THE EFFECT OF VARIATIONS IN MANAGEMENT TECHNIQUES ON CONSTRUCTION PRODUCTIVITY

By

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Abstract of Dissertation Presented to the Graduate School
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THE EFFECT OF VARIATIONS IN MANAGEMENT TECHNIQUES ON CONSTRUCTION PRODUCTIVITY

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Construction is one of the largest industries in the United States, and productivity in construction is a key to the growth in its economy. Measuring and identifying methods of increasing productivity are important roles of the construction manager.

The purpose of this study was to identify the components of management that have the most significant effect on home building productivity and to integrate these components into a paradigm to help guide the industry to increased efficiency.

Productivity was defined as the value added to the house for each day worked. A standardized scale was created to compare the results of various builders' operations. This scale was created by assigning a construction time and a value to each of 49 work activities of a typical Florida single-family house.

Data were collected from each of six construction projects over the duration of the construction process. Data also were collected from 50 Florida home builders whose annual production was at least 100 homes.

A qualitative and quantitative analysis of the data from the construction projects demonstrated that productivity was higher in those projects where a formal schedule was used. The schedule was either provided by management or the superintendent was required to prepare one for each house. Productivity was also higher for projects where an on-site office and/or telephone was provided, and where regular inspections were performed by someone other than the project superintendent. Significantly lower productivity was found where stringent building codes were enforced.

The builder interview data indicated that the most common cause of delay was subcontractors not arriving at the job site when scheduled. Both data sources indicated that there was no significant difference in productivity when multiple job sites were supervised by one superintendent. However, the interview data revealed that productivity decreased as the superintendent's travel distance between jobs increased.

The results of this research present a clear statement to builders that construction productivity is enhanced through formal scheduling and careful assignment of supervisory responsibility. These results will also be useful to educational institutions in developing professional continuing education courses for constructors and superintendents.

CHAPTER I
INTRODUCTION

Construction is one of largest and most important industries in the United States. According to the U.S. Bureau of Census (1990), construction accounts for up to 11 percent[1] of the nation's gross national product (GNP), and private residential construction accounts for approximately 4 percent of the GNP. Since the construction industry is so important to the economy of the U.S., productivity in construction is a source of concern not only for the construction industry, but to others as well.

In a study that included the industrial, commercial and utility segments of the construction industry, The Business Roundtable (1982a) concluded that effective planning and scheduling systems can reduce construction time an average of 10 percent and reduce the cost to the owner by 3 percent. Many segments of the construction industry have adopted various methods for improving productivity, such as the planning and scheduling techniques used in large construction projects. However, in the home building industry, traditional management methods still dominate, and no

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[1] Tables No. 691, 1250, and 1254 of the reference present differing amounts for the value of construction. They show $218.5, $525.9, and $397.7 billion respectively.

systematic study of the effect of variations in management techniques has been conducted. It is expected that effective planning and scheduling systems will reduce the time required to construct single family homes even more than the 10% predicted by The Business Roundtable for other segments of the industry.

Purpose

The purpose of this study was to identify the components of management that have the most significant effect on home building productivity and to integrate these components into a paradigm to help guide the industry to increased efficiency. The purpose is not to improve productivity at the worker or crew level, but to improve the overall productivity of builders' operations. The effects of the following were investigated:

Scheduling

1. Formal Scheduling System.
    - A. Schedule prepared by management.
    - B. Schedule prepared by superintendent.
    - C. Schedule provided to sub-contractors.
    - D. Format of the schedule (CPM, Bar Chart, List of Activities, etc.)
2. No Formal Scheduling System.

Supervision

1. Span of Control.
    - A. Percentage of the work done by subcontractors.

   - B. Full time supervision and/or a site office and telephone.
   - C. The distance traveled by the superintendent to visit jobs.

2. Motivation and Control of Superintendents.
   - A. Superintendent has input into the decisions as to which subcontractors and suppliers to use.
   - B. Someone other than the superintendent makes regular inspections of the work.
   - C. Superintendent paid a regular bonus.
     - 1. Bonus amount determined by fixed formula.

3. Experience.
   - A. The importance the builders place on varying levels of experience for superintendents.
   - B. The amount of experience the builders believe a superintendent needs in order to reach full potential.

Data were collected and analyzed to show which scheduling and supervision techniques are currently being used by substantial operative home builders in Florida. For this study, a substantial operative home builder is defined as a business entity primarily engaged in the construction of single family houses for sale on its own account (Stone, 1991). A model to measure productivity on construction projects using standard processes, materials and designs, with subcontractors performing a major portion of the work was introduced and tested.

Statement of the Problem

Ms. Mary Beth Jones of the National Association of Home Builder's Economics Department reported in a telephone interview that in 1990 there were 859,000 single family residences constructed in the United States at an average cost of $149,400, a total of 133.7 billion dollars. The Bureau of Economic and Business Research (1990) reports that permits for construction of 91,877 single family houses were issued in Florida in 1989. The total value of those houses is not available, but the Bureau of Economic and Business Research (1990) reports the total value on building permits for all residential construction in Florida in 1989 was $9.4 billion.[2] Home building is a major factor in the economy of the nation and the state. In spite of its importance to the economy, little research directed toward improving productivity of home builders has been carried out.

Home building is also a very complex undertaking.

> As the only manufactured good produced by skilled workers brought specially and briefly to the production site, in an inflexible sequence that may or may not move at a real-time pace, home building presents some of the most complicated and sensitive scheduling problems in industrial production. But businessmen can fail to resolve them and survive. (Mayer, 1979, pp. 37-38)

Mayer went on to say that the reason builders could survive and even prosper without resolving these problems was that they could pass the increased cost on to customers who pay the cost in small increments, with depreciating currency, over the life of a mortgage. Another reason is that for the most part, their competition has not solved these problems either.

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[2] Includes single family houses, multi-family, and mobile homes; motels, hotels, and other non-housekeeping residential buildings (Bureau of Economic and Business Research, 1990, p. 307)

According to Ms. Jones, many builders still have not solved these complicated and sensitive problems. She reported that the average time for construction of a single family house was 6.4 months--about 192 calendar days, or approximately 135 working days.

Demonstration projects conducted by Home Builder Associations, Habitat for Humanities and others have shown that with extraordinary planning, scheduling and cooperation among the participants, single family residences can be built in seven days or less. While normal operations will probably never allow consistent production of housing in seven days, the average reported by the NAHB leaves much room for improvement.

The economic benefits of improving single family house construction productivity will be considerable. Considering only the cost of borrowing money, if we assume that for each construction day on average, one-half of the $149,400 cost is accruing construction loan interest ($0 the first day and $149,400 the last day), then the average cost of this interest at 9% per year is $6723 ([(0 + 149,400) / 2] * .09) or $18.42 per day. For each day that the average construction time is reduced, the savings to the industry and the nation's economy will be 16.49 million dollars. This is enough to build 110 average homes or 220 more affordable $75,000 homes. In addition to the savings in interest costs, reducing construction time will yield economic benefits by reducing overhead and allowing more efficient use of personnel and equipment, and a more rapid "turnover" of the builder's working capital.

For a reduction in construction time to be of optimum economical benefit, it must not come at the expense of increasing the total cost of the work. The normal time and the normal cost for performing an activity are the time required and the cost of doing that activity with a normal crew, working normal hours under normal conditions. The shortest time in which an activity or an entire project can be completed is defined as the crash time (O'Brien, 1971). The time required for an activity can be shortened from normal to crash by the use of oversize crews, working overtime, or sometimes using additional material and equipment. Any of these may increase the direct cost of the activity.[3]

An example of what could happen to total project costs for a hypothetical project is shown in Figure 1. For this hypothetical project, the normal time is 34 days and the normal direct cost is $45,600. The crash time is 24 days and the crash direct cost is $50,500. The rate of increase varies with the intensity of the crash efforts, i.e., the number of activities crashed and the total reduction in time. Normal project management costs are $5,500 and will be reduced by $150 for each day that the project is completed early. The value to the owner of early completion is $200 per day.

---

[3] A Business Roundtable report (1980) shows that requiring workers to work 50 hours per week will increase the unit labor cost by up to 46% if workers are paid one and one-half times the normal rate for all time over 40 hours per week and up to 60% if workers are paid double-time for time all over 40 hours.

As Figure 1 shows, the total project cost is reduced for the first 4 days that the project is crashed, and then begins to increase so that reducing the time to less than 26 days will cause an increase in total cost.

Use of effective planning, scheduling and supervision systems will reduce the time required to build each house by providing a smoother work flow, eliminating or reducing the time lost due to workers or materials not being available when and where needed and the time lost due to rework. Use of these effective systems will provide these benefits without crashing the activities and thereby increasing the direct cost.

Hypothesis

Construction time and cost of single family homes can be optimized by the implementation of the most appropriate scheduling and supervision systems.

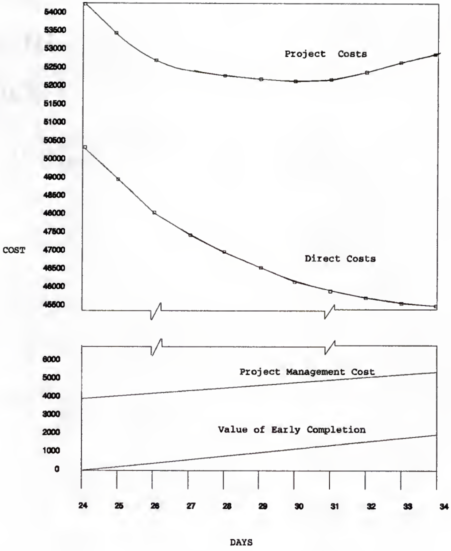

Figure 1
TOTAL COST CURVE

Background

Concern for productivity is not new. Adam Smith discussed how productivity in manufacturing processes could be increased by the division of labor in Wealth of Nations, first published in 1776 (Kiekhofer, 1951). Even in construction, an industry known to be slow in changing and adopting modern methods, serious productivity improvement studies have been carried out for most of the twentieth century.

In 1909, Frank B. Gilbraith published Bricklaying System, which is based on his time and motion studies for improving the production rates of brick layers. In recent years many studies have been directed at improving the production rates of workers. Improvements on Gilbraith's time and motion studies, activity sampling, foreman delay studies, etc., have been developed and carried out to find ways to make workers more productive.

Studies have been directed at improving worker motivation. Some were directed at external factors such as monetary incentives. Others have been concerned with the intrinsic attributes of the work which cause workers to be more satisfied and\or productive. These studies usually assume or infer from the data the relationship between motivation and productivity. Usually the data are interpreted according to the motivational theories developed by Maslow, Hertzberg and McGregor (Bresnen et al., 1984).

Most of these studies deal with how to improve construction productivity at the ultimate source of productivity, the worker, or what Kellog, Howell and Taylor (1981) refer to as the micro-micro level. They are directed toward determining the best system for arranging the material and work flow, and finding methods and procedures to eliminate or reduce wasted motion and time. Some recent studies indicate that improving productivity at this level has reached a point of diminishing returns (Kellog, Howell and Taylor, 1981). This study is not concerned with improving workers' productivity, but with improving the overall productivity of the builders' construction operations.

Planning and scheduling techniques have been developed and refined. There are now numerous deterministic, probabilistic and stochastic methods of arriving at activity and project durations and for the scheduling of the starting and completion of each activity required for a project. There are also numerous graphical and verbal methods of communicating these schedules and plans to the parties involved in the project. Most of the studies pertaining to scheduling are concerned with developing mathematical and mechanical algorithms for scheduling.

Managerial Initiatives

Although the terms "management style" and "leadership" are not clearly defined, an assumption in most of the literature is that these factors can have an effect upon worker motivation, and thus upon productivity. In order to discuss what effect management has on productivity, management must be defined. Management consists of five general functions: planning, organizing, staffing, directing and controlling. These functions grow out of the three basic elements management must deal with: ideas, things and people (Mackenzie, 1969).

Management of these three elements requires skill in three areas: (1) conceptional thinking (this includes planning), (2) administration (organizing and staffing) and (3) leadership (directing and controlling). Many managers are not skilled in all three areas, but to excel, the manager must recognize his or her strengths and weaknesses and make up for any deficiencies through judicial staffing. Each area requires action at various levels from the general to the specific.

To find ways for management to improve productivity in construction, we must consider at what levels management can have an effect. As previously mentioned, Kellog, Howell and Taylor (1981) contend that, barring technological breakthroughs, attempts to improve productivity at the micro-micro level will return marginal benefits, if any.

One factor which makes productivity improvements at this micro-micro level more difficult is the decreasing amount of control which the general contractor or project manager has over the actual performance of the work.

Increased use of subcontractors and specialty contractors to carry out major portions of the work means that general contractors and project managers have less influence on the techniques, methods and equipment used (Bresnen et al., 1984). This large scale use of subcontractors is more prevalent among home builders, but is becoming more common throughout the construction industry.

We can further subtract from the general contractor or project manager's control that degree of planning (the ideas element of management) assumed by the owner or designer of the project. Often the general contractor or project manager has little input into the process of deciding what will be built, where it is to be built, or when the construction will take place. Yet, design features, short lead times and too elaborate planning and scheduling are principal causes of lower satisfaction and, thus it is assumed, productivity, among construction foremen and workers.

In spite of these limitations on the builder or contractor's control, the overall productivity of the operation is still his responsibility. The builder can fulfill this responsibility by carefully orchestrating the work of each of the many parties involved in the work. Overall productivity will be improved if the builder insures a smooth flow of material and workers through the project with a minimum of gaps, or down time, between the completion of one activity and the start of succeeding activities.

Production Improvement Difficulties

A problem prevalent in improving construction productivity studies is defining productivity and establishing a base line against which to measure changes in productivity. Most construction projects, especially large ones which have been the subject of most studies, are unique. This uniqueness makes comparisons among the projects difficult. Unit rates of production, i.e., cubic yards of concrete or square feet of form work, cannot accurately be compared unless the scope and complexity of the projects being compared can be shown to be substantially the same.

A few studies were concerned with more general management structure and control. At least one of these indicates there is a positive relationship between the degree of management control and productivity on a construction project. The authors point out, however, the difficulty of measuring construction efficiency (Danladi and Horner, 1981). In this dissertation, this difficulty will be addressed by utilizing the model introduced to measure the rate of productivity.

Scope

The literature on construction management will be extended through this dissertation by focussing on how managers can improve the operation's productivity with prudent organization and implementation of their scheduling and supervision activities. A method of measuring construction productivity applicable to construction projects where standard processes, materials and designs are used, and where subcontractors perform a major portion of the work will also be presented.

Plan of Research

The systems approach is utilized in this research, not as an objective or end in itself, but as a means to an end--a plan of research. The systems approach consists of both systems design (the application of a broad integrative approach to the reaching of desired objectives) and systems analysis (the methodology for exploring a complex system).

This research consists of a systems analysis of four systems whose interrelationships are shown in Figure 2 on page 17. The prototype system is the home building process as it is commonly carried out by substantial operative home builders in Florida. The measuring system consists of observations of work in progress and interviews with builders. The model system is a conceptual system derived from the analysis of the relationships between the measurements performed and the prototype system. The model system is used to predict the behavior of the prototype. The ideal system is the system which would be in the perfect world, i.e., a world in which all involved had perfect knowledge and perfect control over all aspects of the work to be done.

The systems analysis is essentially an iterative process. After comparison of observed and predicted behavior, the model system is modified to best predict the behavior of the prototype system.

Specific steps to be taken in carrying out this general plan of research are

1. Review the literature and observe the techniques commonly in use by substantial operative builders in Florida.
2. Select projects for observations.
3. Observe the weekly progress of a number of houses in each selected project.
4. Develop an interview questionnaire.
5. Conduct interviews.
6. Analyze data collected by observations and interviews.
7. Modify the model based on comparison of the observed and predicted results of the builder's operations.

Referring to Figure 2, page 17, and the specific steps in the plan of research, we see that the model system develops from the study of typical projects and interviews. The model development is an iterative process of modeling, checking and remodeling. The purpose of the model is to aid in solving the problem and to predict how the system operates. Model development is an abstraction, a figment of the construction manager's imagination. The goal is to create a model which is simple enough to be useful, but still encompass the essentials of the problem so that the results are meaningful (Coulter, 1968-69).

One reason for modeling home building operations is to determine which scheduling and supervision techniques will provide the highest level of productivity. The model should show the effects of scheduling and supervision techniques on home building productivity.

Figure 2 shows an "ideal system" as a block in the research diagram. The "ideal system" for this research is a hypothetical construction schedule and schedule of values based on the researcher's knowledge and information from other builders and financial institutions. The function of this ideal system is to aid in the development of the measuring and model systems and to establish an idealistic basis for optimizing the efficiency of scheduling and supervision systems used by home builders.

Methodology

This study consisted of two parts. The first was to observe and document on a weekly basis the construction of a number of homes built by four selected builders from Central and South Florida (see the Appendix). The second phase of the study was the collection of data using telephone interviews with 50 of the 203 members of the Florida Association of Home Builders who reported that they constructed 100 or more houses per year. ✓

Part One

The selection of builders for part one of the study was based on the following criteria:

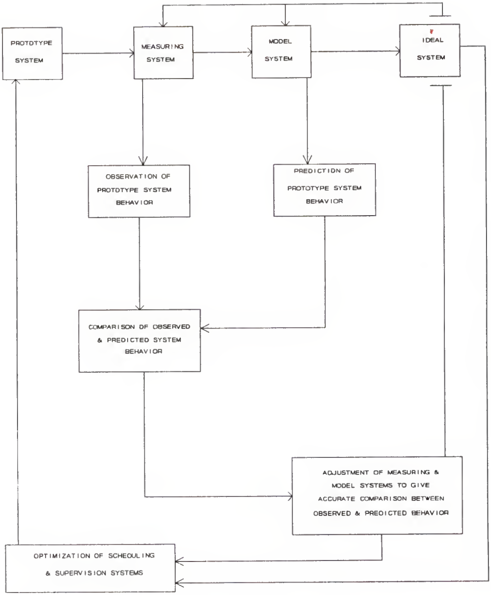
PROTOTYPE SYSTEM
MEASURING SYSTEM
MODEL SYSTEM
IDEAL SYSTEM
OBSERVATION OF PROTOTYPE SYSTEM BEHAVIOR
PREDICTION OF PROTOTYPE SYSTEM BEHAVIOR
COMPARISON OF OBSERVED & PREDICTED SYSTEM BEHAVIOR
ADJUSTMENT OF MEASURING & MODEL SYSTEMS TO GIVE ACCURATE COMPARISON BETWEEN OBSERVED & PREDICTED BEHAVIOR
OPTIMIZATION OF SCHEDULING & SUPERVISION SYSTEMS

Figure 2
RESEARCH PLAN

1. The scheduling and supervision techniques used by each was among those systems commonly used by builders constructing 100 or more single family houses per year.
2. The scheduling and supervision techniques varied substantially among the builders selected.
3. The houses constructed by the builders represented typical home construction in Florida.
4. The builders were willing to cooperate and allow the monitoring of their jobs.

Production rates for the various projects were compared by calculating the percentage of each of the houses completed each week. To do this, various work items were assigned values expressed as a percentage of the total value of the house. The determination of these values is explained in Chapter III.

The purpose of this first phase of the investigation was to determine from field observations whether variations in supervision and scheduling systems had an effect on single family house production rates.

Part Two

The builders to be interviewed were selected at random from a list provided by the National Association of Home Builders. The purpose of this part of the investigation was twofold. The first was to demonstrate that the systems used by the builders observed in part one of the study were being used by many of the larger builders in Florida. The second purpose was to determine whether using different systems affected production rates (see the Appendix).

Organization of Dissertation

Chapter II contains a literature review on construction management and productivity improvement. This review provides an understanding of the evolution of productivity improvements and provides insight into the problems of measuring construction productivity and of quantifying the effects of productivity improvement efforts. Chapter II also includes a description of scheduling systems for construction operations and a review of scheduling and supervision management functions.

Chapter III contains a description of the study methodology. Questionnaire development, sample selection and the interview procedures are explained. The procedures for studying the projects selected for field observation are explained, and the methodology used to compare the production rates among the projects is fully described.

Chapter IV includes an analysis of the data collected and the logical conclusions drawn from this analysis.

Chapter V contains a discussion of how the data support the model proposed in Chapter III. It also contains a discussion of how the results of the study can be used by the industry to improve productivity and how educational programs can be enhanced by utilizing conclusions drawn from this study. A discussion of the need for additional research suggested by this study is also in Chapter V.

CHAPTER II
LITERATURE REVIEW

Introduction

The purpose of this study was to identify the components of management that have the most significant effect on home building productivity and to integrate these components into a paradigm to help guide the industry to increased efficiency.

To develop a theoretical and conceptual underpinning for this study, a thorough review of the literature was necessary. This review provides an understanding of the evolution of productivity improvement efforts. It gives insight into the problems of measuring construction productivity and of quantifying the effects of variations in scheduling and supervision techniques. The literature provides knowledge of the techniques being used by the industry as well as those available but not used. The literature also was reviewed to provide an understanding of the functions of management and how these functions can be carried out.

The first section of this chapter includes a discussion of the evolution of construction productivity improvement efforts. The second section includes a discussion of the problems associated with measuring construction productivity and of quantifying the effects of variations in scheduling and supervision programs. In the third section is an examination of construction supervision and the various scheduling schemes which have been developed for, or used by, the construction industry. The last section is devoted to a discussion of the functions of management as they relate to scheduling and supervision.

Evolution of Productivity Improvement Efforts

People have been writing about productivity for many years. In Wealth of Nations, Adam Smith discussed how productivity in manufacturing processes could be increased by the division of labor (Kiekhofer, 1951). An even earlier reference appears in the Bible.

> Wherefore have ye not fulfilled your task in making brick both yesterday and today, as heretofore? . . . Ye are idle, ye are idle. (Exodus 5:14-17)

This ancient concern for productivity not withstanding, few real gains were made until several pioneers began work in the field early in the twentieth century. The work of some of the most notable of these pioneers is briefly discussed below.

The milestone date in modern productivity improvements is 1903. That is when Frederick W. Taylor, who is known as the Father of Scientific Management, presented his paper on "Shop Management" to the American Society of Mechanical Engineers. Taylor spelled out 13 management "mechanisms" for organizing and controlling work in a manufacturing plant (Alford, 1928).

In 1911, Taylor promoted four objectives of scientific management in his book, Scientific Management: The Principles of Scientific Management. These objectives, quoted by F.J. Drewin, are

> 1. Each element of a man's job was investigated. The aim was to do all job elements in the best and least expensive way. This best way of doing the job was to replace the old rule-of-thumb method.
>
> 2. Formal methods of selecting and training men to do each job with the greatest efficiency were designed by, and to be used by management. Training and development of workers had to become part of the new duties of management. It was not acceptable, under scientific management, that the worker choose his own work and train himself as best he could.
>
> 3. Full cooperation between management and workers was introduced to ensure that all work was done in the best and least expensive way.
>
> 4. Management will take over the responsibility for planning and supervising work. The work was divided between management and workers, with management taking over the greater part of the responsibility. (Drewin, 1982, pp. 20-21)

Taylor believed his methods would be supported by the workers since using them would result in higher monetary rewards. He also believed that manufacturers using his systems should pay workers 30 to 60 percent more than the industry average, since productivity would be 50 to 300 percent higher, and that the higher pay would provide the prime motivation for workers. He did not think that workers should be allowed to choose what work they would do, or when and how they would do it. His methods called for management to choose the men best suited for each job and to prescribe exact procedures for carrying out the work.

Time and Motion Studies

In 1909, Frank B. Gilbreth published *Bricklaying System*, based on his time and motion studies for improving the production rates of brick layers. Gilbreth, who had been trained as a bricklayer and had operated a contracting business, worked closely with his wife, Lillian, a trained psychologist. They searched the literature for contributions from the fields of anatomy, physiology and psychology. Using their experience and studies, the Gilbreths created what they called the "science of eliminating wastefulness resulting from ill-directed and inefficient motions" (Drewin, 1982, p. 23). From this early work are derived today's work studies, or time and motion studies. The Gilbreths also developed their "therbligs" (Gilbreth spelled backwards, with the t and h transposed). Therbligs define 18 basic physical motions and the associated mental process (Drewin, 1982). For ease in recording the motions of workers, the Gilbreths designed a specific symbol for each of the basic motions. For example, the theriblig symbol for select is →, and the symbol for assemble is #.

Like Taylor, the Gilbreths were concerned with improving the worker's existence as well as productivity. They felt that by using their methods, workers would find the work easier and more rewarding.

In 1908, Henry L. Gantt presented another milestone paper in the evolution of productivity to the American Society of Mechanical Engineers. Titled "Training Workmen to Secure Their Cooperation," this paper presented the idea that employees are human beings and want and deserve to be treated as such. According to L.P. Alford (1928), Frank Taylor strongly objected to this paper, and its publishing caused a breakup of the friendship between Taylor and Gantt.

In 1919, Gantt published Organizing for Work, in which he developed his now famous "Gantt Chart." The Gantt Chart is a straight-line chart in which a division of space on the chart represents both a time period and the amount of work to be done during the time period (Coulter, 1979). Lines drawn horizontally through the space represent the amount of work actually done in a given time, versus the amount scheduled to be done. Although Gantt developed his chart for use in manufacturing (Clark, 1938), it has been adapted for and widely used in construction. It is one of the most popular methods of graphically presenting a construction schedule and comparing actual work completed to work planned.

The Gilbreths attempted to improve productivity by reducing or eliminating the inefficiencies of the workers. They searched for ways to make each worker work faster. Gantt and Taylor endeavored to increase productivity--not by causing the workers to work faster, but by having management remove the obstacles which impede the work. They looked for obstacles which affected any of the elements of production such as workers, equipment, management, or capital, and developed methods for removing or minimizing those obstacles (Gantt, 1919).

Later Developments

In recent years, new studies have been produced which are directed at improving the production rates of workers. Improvements on Gilbreth's time and motion studies, activity sampling, craftsman questionnaire studies and other techniques, have been developed and used to find ways to increase productivity.

Activity Sampling

A number of techniques can be used for activity sampling. Some of the most common are work sampling, group timing and five-minute ratings (Thomas and Daily, 1983).

Work sampling consists of measuring the amount of time workers spend doing various tasks. These tasks are classified depending upon the type of work being studied and the objectives of the study. Common classifications are

1. Direct work--work applied directly to tasks necessary to the completion of the project.
2. Essential contributory work--activities which contribute to, and are necessary for carrying out direct work (examples are obtaining and transporting tools, giving and receiving instructions, reading plans, etc.).
3. Ineffective work--activities that do not contribute to direct work (examples are empty-handed travel around the work site, waiting for tools or instructions, etc.).

Measurements can be taken either by observing randomly and recording the activities of the workers, or by use of time-lapse cameras. To be accurate, the workers should be observed by several researchers, and the results should be statistically analyzed.

Like work sampling, group timing is used to measure the time workers spend doing various tasks, but instead of making observations at random, predetermined, fixed-time intervals are used. The time interval may range from 30 seconds to 3 minutes, depending upon the type of work being done and the objectives of the study. At the instant of the observation, the activity of each member of the crew is recorded and classified. This method is particularly useful for the study of short-cycle, highly repetitive group activities (Thomas and Daily, 1983). Repeated observations at randomly chosen times of the day and days of the week are required for this technique to yield meaningful results.

Five-minute rating is a technique for a single observer to quickly make general work evaluations. The name is based on a rule-of-thumb that the time (in minutes) a crew should be observed is equal to the number of workers in the crew, or five minutes, whichever is greater. Thus, a ten-person crew would be studied for ten minutes and a three-person crew would be studied for five. During the period of the study, observations are made as in the group timing technique.

Craftsman Questionnaire

Craftsman Questionnaire (CQ) studies use questionnaires to get information about productivity problems from workers. These questionnaires ask the workers to identify problems on the job, estimate the time lost due to each problem, and rank order the problems according to severity. The workers are also asked to suggest solutions to the problems.

The major objection to CQ is the lack of "evidence validity" (Chang and Borcherding, 1985). Managers are often skeptical of the numerical results of CQ. If this management skepticism can be overcome, CQ can be a useful tool for gathering information about problems on a construction project. If properly introduced and carried out, it will at least let management know how the workers perceive the problems.

Foreman-Delay Surveys

Like the Craftsman Questionnaire, Foreman-Delay Surveys (FDS) use information provided by those directly involved to attempt to identify and analyze job site productivity problems. In FDS, a foreman is asked to complete a form indicating the total worker hours lost due to various administrative elements outside of the foreman's control, but which have significant influence on his crew's performance (Tucker, Rogge, Hayes and Hendrickson, 1982). Typically, FDS will ask foremen to list the worker hours lost due to

1. Changes/redoing work (design change or error)

2. Changes/redoing work (pre-fabrication error)
3. Changes/redoing work (field error or damage)
4. Waiting for materials (stored)
5. Waiting for materials (vender furnished)
6. Waiting for tools
7. Waiting for construction equipment
8. Construction equipment breakdown
9. Waiting for information
10. Waiting for other crews
11. Waiting for fellow crew members
12. Unexplained or unnecessary moves
13. Other

These surveys provide a means for those most likely to be in a position to recognize the causes of delays to report the problems. Some studies seem to indicate that implementing the survey without any subsequent action by senior management can improve productivity (Tucker et al., 1982).

Some of the improvement may be due to the Hawthorne effect.[1] A more important factor may be that causing foremen to recognize the problems allows them to find ways to eliminate or decrease the effects of the problems.

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[1]. In this instance, the Hawthorne effect is used to denote the phenomenon which causes productivity to increase whenever a group or activity is studied and the study is the only change introduced. The reason for this productivity increase is not clear, but may be due to the perceived increase in the status of the workers caused by being chosen for the study (Parker and Ogleby, 1972).

There have also been studies directed at improving productivity by improving worker motivation. Some of these studies have been concerned with external factors such as monetary incentives. Others have been concerned with the intrinsic attributes of the work which cause individuals to be more satisfied and/or productive.

Incentives and Motivation

Alexander Laufer and John D. Borcherding discuss financial incentive programs (FIPs) in "Financial Incentives to Raise Productivity" (1981). An FIP is a plan in which management agrees to pass some or all of the economic benefits of better production rates on to the workers. In order for an FIP to be effective, it must be specifically designed to meet the needs of both the organization implementing it and the workers covered by it. However, Laufer and Borcherding list the following attributes that all programs should have:

1. The program should be simple in operation and easily understood by the workers.
2. Worker's performance should be measured on a group basis.
3. The measures of performance should be specific and as objective as possible.
4. Rewards should be tied to several performance criteria. Specifically the program should heed quality and safety.
5. The standard should not be altered in the course of a project, except by mutual consent.
6. Hourly base rate should be guaranteed.

7. There should be enough spread between the guaranteed base rate and the bonus rate (20-30%).
8. The incentive payment should be in direct proportion to the increased output (All the direct savings should be allocated to the workers).
9. Worker's performance should be measured over as short a period of time as possible, preferably on a weekly, or at most, a monthly basis. The incentive payment should be made as soon as possible after the necessary data is available.
10. The workers and their representatives should participate in the design of the program and in the assessment of its outcomes.
11. Coverage of the program should be extended over as many workers on the site as possible. (Laufer and Borcherding, 1981 p. 754).

Laufer and Borcherding (1981) argue that their research shows that the use of FIP could

1. Increase labor productivity by 3 to 8 percent.
2. Increase the percentage of direct work shown in work sampling by 7 to 18 percent.
3. Increase wages by 3 to 13 percent.
4. Decrease construction time by 8.5 percent.
5. Improve planning, organization and control of the work.
6. Reduce the frequency of accidents by 30 to 40 percent.
7. Decrease the turnover rate by 27 to 32.5 percent.
8. Reduce the number of complaints about quality by 10 percent.
9. Decrease the rate of overtime by 30 percent.

In spite of these benefits, the use of FIPs by the construction industry in the U.S. is limited. This lack of acceptance by the industry may be due to some of the inherent characteristics of construction and construction employment (Maloney, 1983). One of these characteristics is the instability of employment. The construction industry has high rates of voluntary and involuntary turnover. A major portion of this turnover is due to the finite duration of construction projects. Most construction workers expect to have to seek employment with a different firm at the end of a project, and often at the end of a particular phase of a project. Thus, there is a great deal of uncertainty associated with the stability of employment. This uncertainty may make it difficult for workers to accept incentive programs which might actually hasten their departure from the job. Another characteristic is the lack of loyalty between construction workers and employers. As Riemer (1979) points out, construction workers tend to relate to and develop loyalty to their trades rather than their employers. Without loyalty, it is unlikely that the trust necessary to make FIP effective can be generated. This lack of loyalty is, of course, not as severe among managers above the foreman level as among hourly workers.

Studies directed at the more intrinsic attributes of the work show that for many construction workers, the work itself provides sufficient satisfaction and motivation (Borcherding and Oglesby, 1974; Borcherding and Garner, 1981; Maloney, 1981). Thus, job enrichment as it is proposed for industrial work (restructuring job content, providing greater autonomy, etc.) is not necessary. What is necessary is that the job be well planned and managed. Major sources of dissatisfaction are delays while waiting for tools, materials or instructions; falling behind schedule due to poor planning or overly optimistic scheduling; and rework due to revisions to the plans and change orders. (Borcherding and Oglesby, 1974).

These studies usually assume, or infer from the data, the relationship between motivation and productivity. Usually the data are interpreted according to the motivational theories developed by Maslow, Hertzberg and McGregor (Bresnen et al., 1984). However, the literature does not reveal any studies showing that these theories are valid with respect to construction workers.

Problems

Work Faster

Implicit in most of the studies dealing with improving productivity is the idea that, through some means, the individual task necessary to complete the work can be done faster. This may be done by providing better work methods (as studied by Gilbreth), by management removing obstacles to a smooth and rapid work flow (as studied by Taylor and Gantt), by improving motivation through monetary incentives or by providing intrinsic job satisfaction. At least one report indicates that improving productivity at this level has reached a point of diminishing returns:

> At the micro-micro level, only effective employment of labor and equipment offers any hope of improving productivity as the project is executed . . . much has already been accomplished in this area, and productivity improvements henceforth are likely to be marginal at best. (Kellog, Howell and Taylor, 1981, p. 144)

Still, almost all of the literature on construction productivity shows attempts to find the solution to productivity problems at this micro-micro level.

Measuring Construction Productivity

Measuring construction productivity and quantifying the effects of productivity enhancement efforts remains a most difficult task. Two reasons for this difficulty are (1) nonstandard terminology and (2) the application of industrial work study techniques to construction operations (Thomas et al., 1990).

Nonstandard terminology. The first terminology problem is the definition of productivity. Thomas, Maloney, Horner, Smith , Handa and Sanders present the following definitions of productivity (Thomas et al., 1990).

An economist might define it as

$$\text{Productivity} = \frac{\text{Total output}}{\text{Total input}},$$

where the output is measured in the dollar value of the product or in the number of specific units produced, and the input is the total value of all labor, material, equipment, energy and capital used in the production. A state highway department might use

$$\text{Productivity} = \frac{\text{Lane Miles}}{\text{Dollars spent}},$$

while a design professional might prefer

$$\text{Productivity} = \frac{\text{Square Feet}}{\text{Dollars spent}}.$$

Labor productivity may be defined as

$$\text{Labor Productivity} = \frac{\text{Output}}{\text{Labor Cost}},$$

or

$$\text{Labor Productivity} = \frac{\text{Output}}{\text{Work Hours}},$$

or

$$\text{Labor Productivity} = \frac{\text{Estimated Unit Rate}}{\text{Actual Unit Rate}}.$$

The latter definition is the one often used by construction contractors (Thomas et al., 1990).

All of these definitions are quite useful for specific situations where the units of output are standardized and the same work is performed repeatedly over long periods of time. The problem is that construction operations are not made up of standardized tasks, and the tasks are usually of relatively short duration. Since most construction projects are unique in design and the conditions under which the work must be performed varies from site to site, it is difficult to compare production rates among various projects. One study which indicates that there is a positive relationship between the degree of management control and productivity points out this difficulty:

> It would be ideologically perfect but practically unrealistic to seek, for the purpose of comparison, two projects with differing degrees of management control which are otherwise identical. (Danladi and Horner, 1981 p. 707)

It is also difficult to determine the cause of changes in production rates during a particular project. There are numerous internal and external factors that can affect the work.

Even after the researcher has decided on a unit of measurement for rates of production, it is difficult to express the results in a way that is meaningful to the builder. The builder estimates the cost of the work based on the broad circumstances of the project. Thus, he is most concerned with the cumulative average of production rates across the entire project. The researcher is usually able to study the production rates of specific activities for short periods of time (Thomas et al., 1990). It is often difficult to reconcile the differences in the perspectives of the constructor and the researcher.

Application of industrial work study techniques to construction operations. For the most part, the techniques used to study production in construction have been those developed for industrial situations. Motion studies, work sampling, group timing and five-minute ratings are all best suited for situations where repetitive operations are continued for long periods of time. These techniques work best when the production being measured is standardized and well enough understood to be succinctly described. Most construction activities do not meet these criteria. Few tasks on a construction project are routine and the differences in design and site conditions combine to make each project, and most components of each project, unique. This uniqueness makes standardization practically impossible, and makes the concise describing of tasks continuing over a fairly long period of time very difficult. The literature provides little help in solving the problem of measuring productivity in construction. The model used for measuring productivity in this study will alleviate this problem for projects where standard processes, materials and designs are used.

Construction Scheduling

Included in what the constructor considers scheduling are

1. Determining the durations of the various work activities which make up the project.
2. Determining the relationships of the various work activities to one another.
3. Determining the starting and ending date of each work activity.
4. Using the above to find the total project duration.
5. Presenting the above in an understandable format.

There are numerous deterministic, probabilistic and stochastic methods of scheduling which were either developed for or adapted to construction scheduling. These range from the very simple bar chart to highly complex computer modeling systems such as CYCLONE (Halpin, 1977) and PRODUF (Ahuja and Nandakumar, 1985). The reason there is such a variety of scheduling methods for construction is because construction encompasses a wide range of endeavors. A scheduling system best suited for use in building a large hydroelectric dam would probably not be best for a residential apartment. There are, however, some requirements which any scheduling system should meet. According to Carleton Coulter III (1979) these are

> Validity. The information presented to various levels of management should reflect genuine progress. It must represent the true state of affairs.
>
> Reliability. The data presented should be consistent regardless of who obtains them or when they were obtained.
>
> Implementability. The technique should be easy to explain, understand, and operate.
>
> Universality. The scheduling system, in the ideal, should be sufficient to cover the life-cycle of the project. It should contain sufficient information for all levels without using other systems.
>
> Simulation. A system which allows the generation and comparison of alternate courses of action can facilitate the selection process in the proper mix of resources and project phasing.
>
> Forecasting. The determination of the probability of accomplishing future tasks is the requirement of certain construction environments.
>
> Adaptability. A desirable characteristic is to easily incorporate changes. A system must be adaptable if simulation is required, but a system can be adaptable without simulation potential.
>
> Cost. The schedule system should present the required information at the lowest cost of operation. The cost of scheduling is not generally known. Systems with the above features are most costly, and costs are generally

> a function of the project size. Techniques with high fixed costs tend to be less expensive with large projects, and increase with lower scale projects. (Coulter, 1979, p. 6)

Keeping these requirements in mind, and with knowledge of the features of the various scheduling systems, the constructor can select the system best suited to a specific project and organization.

The bar chart is a favorite means of graphically displaying the construction schedule because of its simplicity and ease of understanding. However, it does not provide any means of showing the relationships among the various work activities, and thus cannot meet all of the requirements of construction scheduling. The highly complex modeling systems can consider the relationships among the activities, and by applying probabilities, can consider factors such as weather, material shortages and labor delays. These systems are not popular due to their complexity and a lack of understanding by construction practitioners.

Network Methods

Network methods of scheduling are those with which network diagrams are produced showing the relationships among the work activities as well as the duration of each activity and the total project duration. The network diagram is a flow chart in which the various activities are shown, with arrows or lines indicating the precedence relationships.

Critical Path Method

The critical path method (CPM) is probably the most popular of the network methods used in construction. The principles of CPM are easily understood; however, the mechanics of the program are sometimes complicated, and the resulting network diagram may appear complex and confusing.

The CPM is a deterministic scheduling method since the planner must know the duration of each of the work activities or be able to make a good guess. Thus, it is best suited for projects consisting of activities which are readily understood and for which durations can be accurately determined.

The CPM network can be drawn as either activity on the arrow or activity on the node. When it is drawn as activity on the arrow the CPM begins with a single starting node and proceeds to a single ending node with the various precedence relationships creating one or more paths between the two. The activities are represented by arrows connecting the nodes. Each node is given a unique number. The number of the node at the beginning of an activity becomes that activity's "I" number and the number of the node at the end of the activity becomes that activity's "J" number. Each activity must have a unique combination of a starting (I) number and ending (J) number. Activities do, however, share either I or J numbers. This requirement for a unique I/J number combination makes it necessary for the planner to introduce dummy activities. Two types of dummy activities are used--number dummies and logic dummies. In a case where two or more activities share preceding and succeeding activities, one or more number dummies are required. Logic dummies are necessary when an activity must be preceded by two or more activities and at least one of the preceding activities has succeeding activities not dependent upon all of the other preceding activities.

When the network is drawn as activity on the node, the activities are represented by nodes, and arrows are used to show the precedence relationships. In this case the network starts with one starting activity and proceeds to one ending activity. When there is more than one activity which can be done concurrently at the beginning or end of a project, convention requires the use of a "start" and/or a "finish" node. Drawing the network as activity on the node eliminates the need for dummy activities.

By showing the precedence relationships among the work activities and the duration of each activity, the critical path can be determined by adding up the total durations along each path and finding the longest total. The CPM schedule also shows the amount of float, or how long a noncritical activity may be delayed without extending the duration of the total project.

While a CPM schedule can be generated manually, the large number of calculations and the complexity of the network diagram makes it best suited for computer-aided scheduling, and there are several programs available for desk top as well as mainframe computers.

The CPM system is best suited for projects which meet two criteria: (1) the number of activities is commensurate with the complexity of the project, and (2) the activities have clear precedence relationships which define the required progress from start to finish of the project (Carr and Meyer, 1974).

Program Evaluation and Review Technique

The Program Evaluation and Review Technique (PERT) is similar to the CPM, but the activity durations are determined probabilisticly. Thus, each activity duration becomes a random variable with an expected value and a variance given. Since accurate estimation of true activity duration is not required for the PERT, it is most often used for unique projects in which the various activities have not often been performed before (Naaman, 1974). The PERT network diagrams, like the CPM, can be drawn showing the activities on the node or with activities on the arrow.

Newer versions of both CPM and PERT have included provisions for evaluating time/cost trade offs and for resource leveling. Some computer scheduling programs also allow scheduling some activities in hours and others in days, and include provisions for scheduling activities subject to the finish or start of other activities with lag times. These modifications should alleviate most of the reservations that contractors have expressed about using these programs. The CPM and PERT remain the best known of the network methods of construction scheduling, with the CPM being the most common.

Much of the information contained in a CPM or PERT network diagram can be shown on a Gantt Chart, but this does not allow for showing the precedence relationships. Methods such as the Fenced Bar Chart are attempts to show these relationships on a time scaled-bar chart (Melin and Whiteaker, 1981). Great care must be taken when drawing these charts to avoid crossovers which may become confusing to the reader.

Line of Balance

The line of balance (LOB) technique was first developed during World War II and was presented in its present form in 1962 (Carr and Meyer, 1974). Although LOB has been available for many years, algorithms, which can be used in development of a LOB schedule, have only recently been formalized (Al Sarraj, 1990). Its primary use is for scheduling projects that require construction of repetitive units and for which there are no particular dependencies or precedent relationships among the units, but only among the activities within each unit. The LOB requires three inputs:

1. A network diagram showing the activity precedence relationships of activities in a unit and the time required between the completion of each activity and the completion of the unit.

2. A chart showing the cumulative calendar schedule of unit completion.
3. A progress chart showing the completion of the activities for each unit.

Input 1 above can be a CPM or PERT diagram for one unit, except that the planner must also determine the time required between the completion of each activity and the completion of the unit.[2]

Once inputs 1 and 2 above are provided, it is a simple matter to draw a line (the line of balance) on the progress chart showing which activities in each unit must be completed by the end of each time period if the project is to be completed in the time scheduled.

The LOB technique could greatly enhance a planner's ability to predict resource and worker requirements, but it has not been widely utilized in the United States. This lack of acceptance may be due to relatively little publicity. Both CPM and PERT, which are best suited to complex projects that do not require repetitive activities, have received much more attention.

Described above are just a few of the numerous methods for scheduling construction activity. While much has been written describing the mechanics of these and others, little has been written about why one should schedule, or who should do the scheduling. Some authors have praised each of the systems and others have criticized each. The literature is, for the most part, silent on any difference in the effects of the various methods of scheduling on production.[3]

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[2] In CPM and PERT the time from the start of the unit until the completion of each activity is used.

Management Functions

Management has existed as long as people have undertaken to do things in groups. However, the study of management is relatively new. Frederick Taylor began his studies of how to improve productivity in the 1880s (Pilcher, 1966). It was nearly thirty years later when Henri Fayol introduced the then revolutionary idea that management principles could and should be taught. In 1908, Fayol presented a paper to the congress of a metallurgical society in France in which he explained the process of management. He described management as consisting of five areas, which he called planning, organizing, commanding, coordinating and controlling (Pilcher, 1966).

Fayol's description of the management process is still generally accepted today, although most modern authors label the five areas of management as planning, organizing, staffing, directing and controlling (Mackenzie, 1969; Dessler, 1977). Included in these areas are the three basic elements with which management must deal: ideas, things and people (Mackenzie, 1969). Construction scheduling and supervision involve each of these elements and all of the areas of management at one level or another.

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[3] Borcherding and Garner (1981) do say that overly strict scheduling can lead to lower job satisfaction, and thus, lower productivity, and The Business Roundtable (1982b) concluded that effective planning and scheduling could reduce construction time by an average of 10 percent.

It is important to recognize that in construction the term "management" does not apply only to the board of directors and the senior executives and their functions. Construction management is a function of all members of the organization down to and including the foremen.

Scheduling

Scheduling is planning. It involves establishing the sequence of activities which will make up the project. Decisions must be made regarding when the various materials, workers and equipment required for the project will be available, and arranging activities so that neither materials, workers or equipment are available either too early or too late. Scheduling is most concerned with the "ideas" element of management. Schedulers must be able to conceptualize the flow of work for the complete project from start to finish. They must first be able to break a large and complicated project into small, understandable activities. Then they must be able to see how the various activities will come together to form the complete project.

A discussion of who should develop the schedule follows. In Manage or Be Managed, Don Fuller (1964) devotes a section to the discussion of the level in the organization at which decisions should be made. His logic can also be applied to deciding at what level to do things such as developing a construction schedule. Fuller discusses five factors which should be considered:

1. Futurity--How long into the future will the decision commit the organization? If the decision creates a long-term commitment, it should be made at a high level. Decisions which only affect the near term can be made at a low level.

2. Reversibility--How quickly can the decision be reversed and what difficulties will be involved in the reversal? If the decision will be difficult to reverse, it should be made at a high level.

3. Impact--The extent to which other areas of activities of the organization will be affected. If other areas will be greatly affected, the decision should be made at a high level--at least at a level having responsibility for all areas affected.

4. Quality ("Values")--To what extent does the decision affect the ethical values or basic principles of conduct which govern the organization? If the decision will affect the organization's "values", it should be made at a high level.

5. Periodicity--Is the decision recurrent or rare? Rare decisions should be made at a high level; recurrent or routine decisions should be made at a lower level.

Consider how construction scheduling relates to each of these factors.

1. Futurity--The construction schedule can not outlive the project, which is usually relatively short-lived. In any case, the commitment to complete the project at some point has been made before the schedule is made. From the standpoint of futurity, there is no reason why the schedule should be made at a high level.

2. Reversibility--If progress is properly monitored and adjustments to the schedule made in a timely manner, the difficulties presented by changing or modifying the schedule are not overly troublesome.

3. Impact--Except where conflicts arise due to scheduling resources to more than one project at the same time, the impact on other activities of the

organization are minimal. As long as schedules are reviewed at the organizational level responsible for coordinating the various projects, this factor presents no reason that scheduling cannot be done at the project management or supervision level.

4. Quality ("Values")--The construction schedule should have no impact on these.
5. Periodicity--While each construction schedule is unique since it is made for a unique project, each project requires a schedule. Thus, schedules are recurring and do not require decisions at a high organizational level.

Applying Fuller's logic for determining at what level in the organization a decision should be made shows that construction scheduling can be done at a relatively low level. Allowing the schedule to be developed at the project management or supervision level could lead to reducing the dissatisfaction caused by schedules reported by Borcherding and Garner (1981) since those directly responsible for carrying out the work are less likely to disapprove of a schedule that they helped to create.

Supervision

Supervision is concerned primarily with the directing and controlling functions of management. The construction project superintendent is the first line manager responsible for completing the project (Coulter and Coulter, 1989). The superintendent must arrange for all needed equipment, materials, tools, and workers to be available as required for the project. Inspections must be made to insure compliance with contract requirements and various codes and regulations, and to monitor job progress. The superintendent is also the chief communications link between the workers in the field and upper management. In order to carry out these responsibilities, the superintendent must be given sufficient authority and support from higher levels of management. It is especially important that superintendents be recognized as management representatives and not tradesmen (The Business Roundtable, 1982b).

Problems

Victor Sanvido (1984) presents two major management problems which relate to supervision: information overload and excessive concern for short-term results.

Sanvido points out that information overload occurs because there is a limit on the amount of information a person can process. When a decision maker has too much information to process, the decision-making process slows down. As a result, decisions about what may have been a routine question might not be made until the question becomes a problem or a crisis.

Senior management must be careful to balance the superintendent's need for facts to make valid, reasoned decisions, with the limits of a person's ability to process information. The problem is not having too many pertinent facts relating to any particular decision; it is having information relating to too many decisions.

Sanvido also points out that the control systems of most companies cause increased concern for short-term results. Most budgets make no provision for the cost of making improvements in methods, and schedules usually provide little or no time for planning for these improvements. Many construction companies now use computers for cost and progress control systems. These computers provide the advantage of very quick information feedback to management about the status of a project. Time and money spent to plan and implement systems which might ultimately result in higher productivity will likely cause the computer program to show a budget overrun or progress delays in the early stages of a project.

When cost overruns and/or progress delays are reported at the early stages of a project or operation, senior management should carefully analyze the situation to learn whether these are, in fact, "false" overruns or delays due to careful planning or the implementing of methods which will ultimately result in higher productivity.

There is also the question of the degree of control which a superintendent should or can exercise over the methods used by the workers. Taken to its extreme, Frederick Taylor's ideas of management control over workers would lead to the Marxist idea of capitalist development in which:

> artisans, . . . are transformed into detail workers, stripped of the all-round knowledge of the production of use values, and finally into proletarians having nothing to sell but their ability to work. In this transformation the immediate producer loses control of

> both the product of his/her labor, and the process by which that product is created. (Klitgaard, 1987 p. 33)

Construction managers probably do not want to exercise this degree of control over the workers for at least two reasons. First, as has been mentioned before, some studies have shown that many construction workers find the work sufficiently satisfying, and therefore job enrichment programs are not needed (Borcherding and Oglesby, 1974; Borcherding and Garner, 1981; Maloney, 1981). A higher degree of control over the methods used might remove this source of satisfaction. The second reason is that while it is recognized that a degree of "industrialization" of construction has taken place, i.e., more components are prefabricated in shops and factories and delivered to the job site for installation while fewer are site built, most construction projects are still unique and complicated enough that micro decisions as to how and when to do a task are required. These decisions are beyond the capacity of unskilled, uninformed detail workers.

It is unlikely that construction managers could exercise a high degree of control. As Klitgaard (1987) points out, many construction workers still control, and insist on controlling, decisions as to how to do their work. One reason that they can do this is that, unlike manufacturing, construction management does not own or control all of the means of production (Klitgaard, 1987). Craftsmen own the hand tools used in the work and often own small power tools such as drills and saws. The degree of control that a superintendent can exercise over the workers is also reduced by the increased use of subcontractors. It is not unusual for home builders to use subcontractors for all of the skilled labor and some of the unskilled labor for their projects (Home Builders Institute, 1988). The trend in commercial and institutional construction also is toward increased use of subcontractors in these fields.

Increased use of subcontractors not only reduces the superintendent's ability to control the workers but adds additional levels of communication. The superintendent can no longer issue instructions directly to the foremen and crews, but must communicate with the subcontractor or his representative. This creates problems with what the National Association of Home Builders calls third party management (Home Builders Institute, 1988). The builder or superintendent is now in the position of a third party in the traditional worker/employer relationship. While the superintendent still has the responsibility for completing the work on time, within the budget and according to the contract, he can no longer issue instructions regarding how and when to do the work. When working with subcontractors and their crews, the superintendent's control is almost reduced to what Klitgaard calls "checkbook control." The superintendent can withhold payment until the work is satisfactorily completed, and he can refuse to provide the subcontractor with additional work if excessive problems arise. The fact that many builders are choosing to make extensive use of subcontractors indicates that this is an effective system. However, senior managers must realize that this method may hamper the superintendent's efforts to increase productivity.

Summary

The review of the available literature indicates the following:

1. Most productivity improvements have been directed toward finding methods for causing workers to perform their tasks faster, even though some studies indicate that improving productivity at this level has reached a point of diminishing returns. A few studies have been directed toward identifying and improving the intrinsic characteristics of construction work which provide worker motivation.

2. Most construction operations are not sufficiently standardized so that techniques developed for measuring productivity in industrial operations are adequate for measuring construction productivity. The literature provides little help in finding methods for measuring construction productivity.

3. There is little literature available on the effects of scheduling on construction productivity.

4. There is little literature available to help construction managers determine the most appropriate organizational structure to provide the degree of control best suited to various construction projects.

5. Two major management problems which contribute to productivity problems are (1) information overload, and (2) excessive concern for short-term results.

6. Construction workers control the decisions as how to do their work. This limits the degree of control that management can exercise over the methods and techniques used.

7. Much of the work on construction projects is performed by subcontractors or their employees. This further limits the construction manager's degree of control.

CHAPTER III
METHODOLOGY

Since this study is concerned with the productivity of the builder's overall operations instead of the productivity of workers, the overall time required to build each house is a meaningful and convenient measure of productivity. While time is only one of many productivity variables, it is clearly a very important variable. As mentioned in Chapter I, reducing the time required for construction will result in economic benefits by reducing interest and overhead costs and by allowing more efficient use of personnel and equipment and a more rapid turnover of the builder's working capital.

In order to study productivity, it is necessary to define the term and a unit of measurement. A classic definition of productivity is

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}.$$

For this study, output is defined as the value of work in place (VWP) and input is defined as days under construction (DUC). So the formula becomes

$$\text{Productivity} = \frac{\text{VWP}}{\text{DUC}}.$$

Definition of Terms

For our definition of productivity, VWP is expressed as the percentage of the value of the total house of all work completed to date. In order to measure the value of work in place, a value for each of 49 work items or events was determined. These values were found by dividing the cost for each of these items by the total cost of the house as reported by two Florida home builders. The resulting values were averaged with corresponding values from a composite of schedules of values used by two Gainesville, Florida, lenders. The resulting table of values is shown in Table 1.

This definition of output was chosen for three reasons:

1. It provides a convenient unit of measurement.
2. It provides a unit of measurement which is consistent among the projects studied.
3. It provides a model which can be used for measuring productivity on other construction projects which use standard processes and for which the end use is similar. School and prisons are examples of such projects.

Days under construction (DUC) is defined as the number of calendar days from the day the building permit is issued until the final building inspection. Calendar days were chosen instead of work days for two reasons:

1. Calendar days have a direct effect upon interest cost and the reduction of this cost is a significant benefit of faster production.
2. This provides a convenient and consistent unit of measurement. Not all builders and subcontractors observe the same holidays.

For this study a home builder is defined as a person or business entity engaged primarily in the construction of single family houses for sale on their own account rather than as contractors (Stone, 1991).

Model Schedule

A model schedule for construction of a typical single family home in Florida was also created. A typical single family home is defined for this study as one which contains at least 750 and not more than 3500 square feet of living area, no basement and with a structure of either concrete block or wood frame. This schedule is based on the researcher's years of experience in home building and numerous discussions with other home builders. It is an idealistic schedule and contains no allowances for weather or any other contingencies.

If a schedule were made for houses built in locations other than Florida where house types are different, or if the schedule was for use by a custom house builder, it would vary considerably from the model schedule.

This schedule is admittedly idealistic. However, four builders have reviewed the schedule and all have agreed that it would not be impossible to meet if, as one said "everything goes just right." Due to the nature of construction in general and home building in particular, it is not expected that all of the activities will ever happen exactly as scheduled, but a nearly optimal schedule will provide the best gauge for measurement. The following assumptions were made in creating the schedule:

1. So long as the houses are of similar complexity and of a size typically built by home builders as defined above, the size and complexity of the house will not be a factor in the schedule.

2. There will be no delay due to change orders or rework.

3. Skilled subcontractors and workers are available in sufficient quantity to carry out the work without delay.

4. All required materials are readily available and will be delivered on time.

5. All required inspections will be made without unexpected delay.

Discussion of Model Schedule Assumptions

A nationwide survey of facility managers, corporate designers and architect/engineering firms identified four major contributors to construction delays and cost overruns (Coulter and Cox, 1982). In rank order these are

1. Inadequate or incomplete design.
2. Change orders and modifications.
3. Subcontractor problems.
4. Shortcomings in field inspection.

According to Coulter (1990) problems with design, including changed scope, size and complexity account for 45% of all construction delays and cost overruns. For the projects studied these problems are not a factor in the schedules since the houses are all similar in complexity. Review of the plans used in the projects studied show that the houses are similar in the number of partition walls, closets, mechanical and electrical fixtures and windows. These items constitute the most labor intensive components of home building. The similarity of these components among the projects studied, and the repetitive use of each plan lends validity to the assumption that the size and complexity of the houses built (1 above) will not be a factor in the schedule.

Change orders (2 above) can account for 35% of construction delays and cost overruns (Coulter, 1990). Custom home building like commercial, industrial and institutional construction, are affected by this problem due to changing owner requirements during the construction process. For this study all of the projects consisted of standard homes built for sale by the builder and without user control, and changes did not affect the schedules or costs.

Lack of skilled workers, subcontractors and materials and supplies (3 above) can account for 35% of construction delays (Coulter, 1990). In construction the availability of these depends on the demand. When construction activity is low, such as in the current 1991 depressed market, construction workers and subcontractors tend to move to areas of higher demand, withdraw from the market or seek work in other industries. When construction demand is high, such as during the 1985-1988 building boom in South Florida, craftsmen, subcontractors and materials become short in supply. During the research period of 1989-1990, the construction market was in relative equilibrium. The supply of workers, subcontractors and supplies was in balance with the construction demand.

Poor quality control and failed inspections account for 5% of construction delays (Coulter, 1990). Inspection delays (4 above) are caused by two reasons; delays due to incorrect timing (no show by the inspector) and failed inspections. Effective scheduling and supervision systems should minimize these problems.

The model schedule is shown in Table 2 in the form of a list of activities with the days into construction for the start and finish of each activity. By combining Tables 1 and 2, the productivity per day under construction required by the model schedule can be seen (see Table 3).

Research Model

Construction time

Nine factors affecting the time for construction were identified, which resulted in the following functional relationship:

$$T: T(S_m, SC_m, SC_s, SC_u, SP_B, SP_I, SP_O, SP_E, SP_e)$$

where

T = Total construction time

S_m = The time allowed by the model schedule

SC_m = The effect of management providing a schedule

SC_s = The effect of requiring the superintendent to prepare a schedule

SC_u = The effect of providing subcontractors with a copy of the schedule

SP_B = The effect of paying the superintendent a regular bonus

SP_I = The effect of someone other than the superintendent making regular inspections

SP_o = The effect of having a superintendent work in only one subdivision at a time

SP_E = The effect of management emphasis on high productivity

SP_e = The effect of superintendent experience

For this model, the following assumptions were made:

1. All superintendents studied are capable of building approximately the same number of houses per year. Thus, overhead cost for supervision will not vary if the superintendent works to capacity.
2. Direct costs and miscellaneous costs are the same for all builders.
3. Interest costs vary directly with the time required to construct each house.
4. On average, half of the construction loan is outstanding each day that the house is under construction.

There are other factors which may affect the time for construction. Some of these factors, such as weather, are uncontrollable. Others, such as the attitudes and motivation of the workers and subcontractors, are outside of the cope of this study.

Data Collection

Four Florida home builders were selected for part one of this study using the criteria for selection presented in Chapter I, which are

1. The scheduling and supervision techniques used by each was among those systems commonly used by builders constructing 100 or more single family houses per year.
2. The scheduling and supervision techniques varied substantially among the builders selected.
3. The houses constructed by the builders represented typical home construction in Florida.
4. The builders were willing to cooperate and allow the monitoring of their jobs.

One of the builders was located in Tampa and had three projects (one in Hillsborough and two in Pasco County) where differing factors affecting the time for construction were present (see Tables 4, 5 and 6). This builder is referred to in the data as Builder 1-1, 1-2, and 1-3. Builder 2 was located in Seminole County and had projects in Orange and Seminole Counties. Builders 3 and 4 were located in Broward County and were working only in that county. Each of the projects studied was under the supervision of only one superintendent. The superintendent for Builders 1-1, 1-3, 2, and 3 all were responsible for work in more than one subdivision at the time.

During the study, each of the projects was visited weekly and the progress made during the week was recorded. Notes were made regarding whether or not the superintendent was present at the job site, any "red tags" (inspection rejections) and any unusual events or problems observed.

The progress made was compared to our model schedule to determine the builder's productivity relative to the model. If the builder was out of phase with our schedule, credit was given for all actual construction progress. This was done by summing the model schedule durations for all activities completed to determine the total days progress completed. It was possible for a builder to be out of phase since some of the work activities are not on the critical path and can be performed in a different sequence without affecting the total time for construction.

The data were analyzed to determine if there were significant differences among the means of average daily production relative to the model schedule, and if there were differences, which of the factors in the model may have had an effect (see Table 11).

This part of the research provides a method of determining from actual observations how the construction progressed on the houses. This provides an objective view of the results of the builders' operations since it frees the researcher from total reliance upon the memories and frankness of the respondents to a survey.

For part two of the study, 50 builders selected randomly from a list provided by the National Association of Home builders were interviewed (see the questionnaire in the

Appendix.) The responses to the questions were analyzed using tests of the means or tests for correlations between variables as applicable to determine whether there are any significant differences or correlations among the builders.

Questionnaire Development

The questionnaire was developed with the goal of determining how the home builders in Florida structure their scheduling and supervising systems and what the results of these systems are. Another goal was to confirm that the systems used by the builders studied in part one were being used by many of the large builders in Florida.

Questions 1 through 5 of the questionnaire were developed to determine that the respondent was a member of the population being studied. Question 4 was also used to indicate whether the location of the builder's operations is a factor in construction time. Questions 6 through 9 were designed to determine whether, for home builders as defined on page 47 above, size and price of the builders product is a factor in the time required for construction. Questions 10 through 20 and 27 through 32 were designed to determine whether a substantial portion of the large volume builders in Florida use scheduling and supervision techniques similar to those used by the builders studied in the field observations part of the research and whether these techniques affect the time of production. Question 21 was designed to determine whether the builders placed more emphasis on rapid construction or consistency of construction production.

Questions 22 and 23 were designed to determine how much experience the builders believe is required for construction superintendents. Questions 24 and 25 were used to determine what the builders consider to be the greatest strengths and weaknesses of superintendents. Question 26 was developed to determine how the builders or superintendents react to what the builders believe is the greatest weakness of superintendents. Question 33 was designed to see if the builders believe that their scheduling systems are effective. Questions 34 through 39 were developed to determine how long the builders believe is necessary to construct a single family residence. Questions 40 and 41 were developed to determine what the builders perceive as the most prevalent cause of construction delay. Questions 42 and 43 were asked to determine how much of the construction time the builders feel is due to unnecessary delay. Question 44 was designed to solicit general information about any problems the builders consider important.

Sample Selection and Interviews

A list of all of the Florida members of the National Association of Home Builders (NAHB) was provided by that organization. Since the NAHB could not provide a list on only those builders who build 100 or more units per year, the complete membership list was used to start the sample selection process. Using a computer generated random number for a starting point, the third on the list was selected as the first to contact. Next, every fourth member on the list was selected. The list provided by the NAHB did not include phone numbers, so a copy of the telephone yellow pages was secured from the University of Florida library. If a builder selected was not included in the telephone list, or if the builder called did not wish to participate, or if the builder's answer to question 2 or 3 indicated that the respondent was not a member of the target population, the next builder on the list was selected. This process was continued until 50 suitable responses were secured.

At the beginning of the interview, the respondent was assured that all information would be held confidential and that data would only be reported in the aggregate. If at any time any of the respondents appeared unwilling or unable to answer the questions, they were thanked for their participation and the next builder was contacted. The interviews required from 10 to 20 minutes to conduct. Very few of the builders called expressed an unwillingness to participate, although many did not meet the criteria established for the target group.

Results of studies such as this one have not yet been published. The National Association of Home Builders conducts annual surveys of its members, but those data are reported on a nation-wide basis and not by the individual state. No one has conducted a study similar to part one of this study. The results of this study can be used by home builders to compare the results of their operations to the sample and to find how to structure their scheduling and supervision systems for maximum results. The results can be used by education programs to show students how builders operate and the best way for builders to operate.

TABLE 1

PERCENT OF COSTS

	ITEMS	Builder 1	Builder 2	Lender Composite	Average	Sample variance
1	PERMITS & FEES	8.8%	7.4%	1.2%	5.801%	0.162%
2	SURVEY	0.4%	0.3%	0.3%	0.304%	0.000%
3	CLEAR LOT	2.7%	1.2%	2.5%	2.145%	0.007%
4	FILL AND GRADE	2.7%	1.6%	1.6%	1.959%	0.004%
5	LAY OUT & DIG FOOTING	0.9%	0.0%	0.5%	0.471%	0.002%
6	FOOTING INSPECTIONS	0.1%	0.0%	0.1%	0.047%	0.000%
7	POUR FOOTING	0.9%	0.0%	0.5%	0.471%	0.002%
8	LAY FOUNDATION WALL	1.6%	0.0%	0.9%	0.848%	0.007%
9	FILL SLAB	0.0%	0.0%	0.0%	0.000%	0.000%
10	ROUGH PLUMBING UNDER SLAB	2.4%	1.9%	1.8%	2.032%	0.001%
11	SOIL POISON	0.2%	0.3%	0.1%	0.185%	0.000%
12	FORM & SET UP SLAB	0.0%	0.0%	0.0%	0.000%	0.000%
13	SLAB INSPECTIONS	0.1%	0.0%	0.1%	0.046%	0.000%
14	POUR SLAB	2.5%	6.6%	1.4%	3.520%	0.073%
15	LAY EXTERIOR WALLS	8.8%	5.1%	5.1%	6.303%	0.046%
16	POUR BOND BEAM	1.0%	0.0%	0.6%	0.525%	0.003%
17	ROUGH CARPENTRY	14.6%	21.1%	21.2%	18.949%	0.142%
18	SOFFIT & FACIA	0.8%	1.2%	1.3%	1.116%	0.001%
19	DRY IN	0.6%	0.0%	0.0%	0.209%	0.001%
20	ROUGH PLUMBING INTERIOR	2.1%	1.9%	1.8%	1.928%	0.000%
21	HVAC DUCTS	1.6%	2.5%	1.7%	1.944%	0.003%
22	ROUGH ELECTRICAL	1.6%	1.9%	2.3%	1.942%	0.001%
23	WINDOWS	2.3%	2.3%	3.2%	2.617%	0.003%
24	ROOFING	2.9%	2.3%	2.3%	2.514%	0.001%
25	BATT INSULATION	1.3%	1.8%	1.1%	1.399%	0.001%
26	HANG DRYWALL	4.3%	0.0%	2.8%	2.368%	0.048%
27	TAPE DRYWALL	0.4%	0.0%	0.0%	0.150%	0.001%
28	CLEAN UP & GRADE EXTERIOR	2.4%	0.3%	0.0%	0.898%	0.018%
29	FINISH DRYWALL	0.3%	5.8%	2.9%	3.005%	0.074%
30	EXTERIOR STUCCO	0.7%	2.8%	0.0%	1.161%	0.021%
31	CERAMIC TILE & MARBLE	3.7%	2.9%	1.9%	2.809%	0.008%
32	TRIM CARPENTRY	0.7%	4.7%	6.7%	4.044%	0.093%
33	FORM DRIVES WALKS & PATIOS	1.3%	0.0%	0.0%	0.449%	0.006%
34	PAINT INTERIOR	1.5%	1.2%	2.9%	1.853%	0.008%
35	POUR DRIVES WALKS & PATIOS	1.5%	2.4%	2.9%	2.274%	0.005%
36	WALLPAPER	1.0%	0.0%	1.1%	0.706%	0.004%
37	PAINT EXTERIOR	1.9%	1.2%	2.9%	1.999%	0.007%
38	CABINET & VANITIES	4.4%	5.4%	7.2%	5.657%	0.020%
39	PLUMBING TRIM	2.0%	1.9%	1.8%	1.901%	0.000%
40	DELIVER APPLIANCES	0.9%	0.3%	2.8%	1.676%	0.011%
41	HVAC TRIM	0.8%	2.5%	2.6%	1.970%	0.010%
42	MIRRORS & MEDICINE CABINETS	0.6%	0.2%	0.3%	0.376%	0.000%
43	ELECTRICAL TRIM	3.2%	1.9%	2.3%	2.474%	0.004%
44	LANDSCAPE & SOD	3.5%	1.0%	2.4%	2.320%	0.015%
45	CARPET & VINYL	0.6%	4.2%	4.4%	3.069%	0.045%
46	HARDWARE	2.7%	0.0%	0.0%	0.909%	0.025%
47	CLEAN UP	0.5%	0.0%	0.5%	0.349%	0.001%
48	PUNCH OUT	0.0%	0.5%	0.0%	0.180%	0.001%
49	FINAL INSPECTIONS	0.1%	0.3%	0.0%	0.130%	0.000%
	Total	100.00%	100.00%	100.00%	100.00%	

TABLE 2
MODEL SCHEDULE

	Activity	Duration	Start	Finish
1	CLEAR LOT	1	1	1
2	FILL & GRADE	1	2	2
3	LAY OUT & DIG FOOTING	1	3	3
4	FOOTING INSPECTION	1	4	4
5	POUR FOOTING	1	5	5
6	LAY FOUNDATION WALL	1	8	8
7	FILL SLAB	1	9	9
8	ROUGH PLUMBING UNDERGROUND	1	10	10
9	SOIL POISON	1	11	11
10	FORM & SET UP SLAB	1	12	12
11	SLAB INSPECTIONS	1	15	15
12	POUR SLAB	1	16	16
13	CURE SLAB	2	17	18
14	LAY EXTERIOR WALL	3	19	23
15	POUR BOND BEAM	1	24	24
16	ROUGH CARPENTRY	4	25	30
17	DRY IN	1	31	31
18	ROUGH PLUMBING INSPECTION	1	31	31
19	SOFFIT & FACIA	2	31	32
20	HEAT & A.C. DUCT	1	32	32
21	ROOFING	1	32	32
22	ROUGH ELECTRICAL	1	33	33
23	INSTALL WINDOWS	1	33	33
24	BATT INSULATION	1	36	36
25	FRAMING INSPECTION	1	37	37
26	HANG DRYWALL	2	38	39
27	TAPE DRYWALL	2	40	43
28	FINISH DRYWALL	1	44	44
29	CLEAN UP & GRADE	1	45	45
30	CER. TILE/MARBLE	1	45	45
31	TRIM CARPENTRY	2	45	46
32	FORM DRIVES/WALK	1	46	46
33	PAINT INTERIOR	1	47	47
34	POUR DRIVES/WALK	1	47	47
35	DELIVER APPLIANCES	1	50	50
36	CABINETS & VANITIES	1	50	50
37	EXTERIOR STUCCO	2	50	51
38	WALLPAPER	1	51	51
39	PLUMBING TRIM	1	51	51
40	PAINT EXTERIOR	1	52	52
41	MIRRORS & MEDICINE CABINETS	1	52	52
42	ELECTRICAL TRIM	1	53	53
43	LANDSCAPE & SOD	1	53	53
44	HEAT & A.C. TRIM	1	54	54
45	CARPET & VINYL	1	57	57
46	HARDWARE	1	58	58
47	CLEAN UP	1	59	59
48	PUNCH OUT	1	60	60
49	FINAL INSPECTION	1	61	61

TABLE 3
MODEL SCHEDULE AND COSTS

	Activity	Duration	Start	Finish	Cost	Cumulative Cost
1	CLEAR LOT	1	1	1	8.25%	8.25%
2	FILL & GRADE	1	2	2	1.96%	10.21%
3	LAY OUT & DIG FOOTING	1	3	3	0.47%	10.68%
4	FOOTING INSPECTION	1	4	4	0.05%	10.73%
5	POUR FOOTING	1	5	5	0.47%	11.20%
6	LAY FOUNDATION WALL	1	8	8	0.85%	12.05%
7	FILL SLAB	1	9	9	0.00%	12.05%
8	ROUGH PLUMBING UNDERGROUND	1	10	10	2.03%	14.08%
9	SOIL POISON	1	11	11	0.19%	14.26%
10	FORM & SET UP SLAB	1	12	12	0.00%	14.26%
11	SLAB INSPECTIONS	1	15	15	0.05%	14.31%
12	POUR SLAB	1	16	16	3.52%	17.83%
13	CURE SLAB	2	17	18	0.00%	17.83%
14	LAY EXTERIOR WALL	3	19	23	6.30%	24.13%
15	POUR BOND BEAM	1	24	24	0.53%	24.66%
16	ROUGH CARPENTRY	4	25	30	18.95%	43.61%
17	DRY IN	1	31	31	0.21%	43.82%
18	ROUGH PLUMBING INSPECTION	1	31	31	1.93%	45.75%
19	SOFFIT & FACIA	2	31	32	1.12%	46.86%
20	HEAT & A.C. DUCT	1	32	32	1.94%	48.80%
21	ROOFING	1	32	32	2.51%	51.32%
22	ROUGH ELECTRICAL	1	33	33	1.94%	53.26%
23	INSTALL WINDOWS	1	33	33	2.62%	55.88%
24	BATT INSULATION	1	36	36	1.40%	57.28%
25	FRAMING INSPECTION	1	37	37	0.00%	57.28%
26	HANG DRYWALL	2	38	39	2.37%	59.64%
27	TAPE DRYWALL	2	40	43	0.15%	59.79%
28	FINISH DRYWALL	1	44	44	3.01%	62.80%
29	CLEAN UP & GRADE	1	45	45	0.90%	63.70%
30	CER. TILE & MARBLE	1	45	45	2.81%	66.51%
31	TRIM CARPENTRY	2	45	46	4.04%	70.55%
32	FORM DRIVES/WALK	1	46	46	0.45%	71.00%
33	PAINT INTERIOR	1	47	47	1.85%	72.85%
34	POUR DRIVE/WALK	1	47	47	2.27%	75.13%
35	DELIVER APPLIANCE	1	50	50	1.68%	76.80%
36	CABINETS & VANITIES	1	50	50	5.66%	82.46%
37	EXTERIOR STUCCO	2	50	51	1.16%	83.62%
38	WALLPAPER	1	51	51	0.71%	84.33%
39	PLUMBING TRIM	1	51	51	1.90%	86.23%
40	PAINT EXTERIOR	1	52	52	2.00%	88.23%
41	MIRRORS & MEDICINE CABINETS	1	52	52	0.38%	88.60%
42	ELECTRICAL TRIM	1	53	53	2.47%	91.08%
43	LANDSCAPE & SOD	1	53	53	2.32%	93.40%
44	HEAT & A.C. TRIM	1	54	54	1.97%	95.36%
45	CARPET & VINYL	1	57	57	3.07%	98.43%
46	HARDWARE	1	58	58	0.91%	99.34%
47	CLEAN UP	1	59	59	0.35%	99.69%
48	PUNCH OUT	1	60	60	0.18%	99.87%
49	FINAL INSPECTION	1	61	61	0.13%	100.00%

CHAPTER IV
DATA ANALYSIS AND DISCUSSION

Data Analysis

Field Observations: Builder Information

Table 4 contains the answers to questions 1 through 9 of the questionnaire for the projects studied during the field observations (part one) of the research.
The data show that the builders had been in business from 4 to 15 years; the average time in business was 11.33 years. There is a negative correlation between the time in business and the time of construction (r = -.6518), but this correlation is not statistically significant at the 90% confidence level (P =.1607).

The builders observed reported that they built from 60 to 300 houses in 1990, and that the individual superintendents supervising the projects observed built from 60 to 90 houses. There is a correlation between the number of houses built and the time for construction. For the builders, the correlation (r = .8135) is statistically significant at the 90% level (P = .0489), but for the superintendents (r = .4634), the relationship is not statistically significant (P = .3536).

Table 4, page 90, shows that neither the builders or the superintendents expect that their total production in 1991 will be much changed from 1990.

The builders work in one, two or three counties, but the individual superintendents work in only one or two. Analysis of variance shows that there is no significant difference for time of construction among the number of counties worked in (P value = .1713 for the builders and .9950 for the superintendents). The size of the areas being built in by the builders has not changed recently.

Table 4 also shows the sales prices of the least expensive, average and most expensive houses built by the builders and the size in square feet of living area of the smallest, average and largest houses built by the builders. The only significant correlation shown between these factors and the time of construction is for the size of the largest house normally built by the builders (r = .8354 and P = .0384). The correlation coefficient for the size of the average house built by builders and the time for construction is .2287 and the P value is .5790.

Field Observation: Supervision

Table 5 contains the answers to questions 10 through 26 of the questionnaire for the projects studied during part one of the research. The first section of Table 5 shows information about factors important to the superintendent's span of control.

All of the builders observed used subcontractors for 100% of the skilled work on their projects. This means that all of the work except supervision and perhaps general cleanup and punchout is performed by subcontractors or their employees.

Table 5 shows that four of the superintendents were working in more than one subdivision. It shows that three of these were working in three subdivisions and one was working in two. Analysis of variance shows no significant differences among the means of time of construction for the number of subdivisions worked in.

The table shows the estimated distance that the superintendents must travel to cover all of their jobs. Correlation analysis shows no statistically significant correlation between the distance traveled and the time of construction ($r = .1867$ and $P = .7233$).

The table shows three of the projects had an office and/or telephone on the site for the superintendent's use, and three did not. Analysis of variance shows that the difference between the means for those projects which had phones or offices and those that did not are not significantly different at the 90% confidence level. However, pairwise comparison by LSD intervals shows that differences are significant at the 89% level.

The second section of Table 5 shows information about superintendent motivation and control factors. It shows that for three of the projects studied, purchasing departments decide upon and negotiate with subcontractors and material suppliers. Management does this for the other three. One of the builders who reported that management decides upon and negotiates with subcontractors and suppliers said that the superintendent had input into the decisions and could veto a selection.

Of the projects observed, four have someone other than the superintendent make regular inspections as the work progresses. On average, houses in these projects were completed in 42.73 days less than in the other three projects. This is a significant difference ($F = 20.23$ and $P = .0108$).

For three of the projects, the inspections were made at the time the house was complete, and for one, the inspections were made at framing stage as well as at completion. When these inspections were made did not significantly affect the time for construction.

The builders reported that regular bonuses are paid to five of the six superintendents observed. For four of the superintendents, the bonuses were determined using a formula which the superintendent knew. The other bonus was determined arbitrarily by management. The data show no significant difference in time for construction for either, whether bonuses are paid or how the amount is determined.

The third section of Table 5 shows the experience level of each of the superintendents observed and the relative importance that the builders place on the experience of superintendents. The experience of the superintendents ranged from 4 to 18 years, with an average of 10.67 years. There is no significant correlation between the level of experience of the superintendents and the time of construction.

The builders all considered the first five years of experience to be very important. Only one of the builders considered the second five years of experience to be of some importance, and none thought the experience past ten years was important at all.

One of the builders believes that a superintendent can reach full potential with ten years experience; the others believe that five years is sufficient for superintendents to reach their full potential.

The last section of Table 5 shows what the builders believe are the greatest weaknesses and strengths of the superintendents. Planning was given as the greatest weakness of three of the superintendents; lack of interest in quality control, inattention to details and communications skills were given, one each, as the greatest weakness of the other three superintendents. When asked how the superintendents handled these weaknesses, builders responded to the effect that the superintendents did not, but that the builders took various steps to work around the weaknesses.

Interest in cost control was listed as the greatest strength for four of the superintendents. Planning was considered the greatest strength of one, and one builder said that the superintendent was very strong in planning, attention to details and cost control.

Field Observations: Scheduling

For three of the projects observed, management provided schedules for the superintendents to follow. For one, the superintendent was required to prepare a schedule for each job. For two of the projects, schedules were neither provided by management or required of the superintendents. All of the projects which used schedules prepared the schedules in the form of a list of activities with dates for completing the activities. The average time of construction for the projects where schedules were used was 42.73 days less than the average of those where schedules were not used. Whether the schedule was provided by management or required of the superintendent did not significantly affect the time of construction. Only one of the builders provided subcontractors copies of the schedules. The others relied on telephone calls from the superintendents to notify the subcontractors when to do their work.

When the builders were asked what percentage of the houses in each project observed were completed on schedule, the responses ranged from 50% to 95%. It is interesting to note that all of the builders except one said that the average time to build a house was greater than the time allowed by their schedule (see Table 6).

In all cases, the average time required to build each house observed during this study was greater than the builder's schedule allowed. The time required to build each house was greater than the average time reported by the builder for five of the six superintendents observed. For Builder 1-2 the average time of construction observed was 75.5 days per house. The builder reported that on average, houses in that project took 80 days to complete and that the schedule allowed 75 days. See Tables 10 and 11 for rankings of the builders according to average time of construction and conformance to their own schedules.

Builders 3 and 4 are located in Broward County which requires following the South Florida Building Code, and the other builders are in areas which follow the Southern Standard Building Code. The South Florida Code is more stringent in some respects, and the Building Department in Broward County requires 27 inspections while the Building Departments in Central Florida require 12. To account for these differences, the observed time for Builders 3 and 4 was adjusted by 15 days (one day for each additional inspection) and the builders were ranked according to adjusted observed progress. This adjustment moved Builder 4 from fourth to second in the ranking and Builder 3 from fifth to fourth (see Table 12).

When asked what was the least amount of time in which they could reasonably expect a build a house, Builder 1 said 75 days and Builders 2, 3, and 4 said 90 days. For all of the builders except Builder 3, the time given matches the time allowed by their schedules. Builder 3's schedule allows 30 days more than the least time in which he could reasonably expect to build a house.

Only Builder 2 felt that houses could be built faster if fewer were being built. However, Builders 1-1, 1-2, 1-3 and 2 believed that the houses could be built faster if they were physically closer together.

When asked what is the most common cause of delay, all of the builders said that subcontractors not showing up when scheduled was the most common. When asked how much delay this causes, the responses varied from 4 to 5 days to 10 to 15 days (see Table 6).

When asked how much time was lost waiting for inspections, the answers ranged from 10 to 30 days. Builder 3 who said 30 days added that much of the delay was due to reinspection being frequently required.

All of the builders observed believe that it would be better to take an average of 80 days to build each house if the difference between the slowest and fastest is 5 days, than to average 75 days per house if the difference between the slowest and the fastest is increased to 20 days.

Questionnaire Data: Builder Information

The following is a question by question discussion of the data collected via the questionnaire:

Question 1 shows that the builders have been in the business an average of 10.68 years. The youngest has been in the business for 3 years and the oldest for 23 years. There is no significant correlation between the years in business and any of the other questions on the questionnaire.

Question 2 shows the number of houses built in 1990 by the respondents. The minimum number of units built by any respondent was 100 (the target group minimum) and the most units built by any respondent was 200. The average number of units built by the respondents was 150.54. The number of units built correlates positively with Question 13 ("What is the maximum distance, in miles, that your superintendents have to travel between jobs?"). Whether having to travel farther between jobs is a natural consequence of building more houses or some of the builders are not carefully planning superintendent assignments is unclear.

Question number 3 shows that most of the builders expect to build about the same number of units in 1991 as they built in 1990. Of the 50 builders questioned, 10 expect to build more in 1991 than in 1990, and 7 expect to build less. The average number expected in 1991 is 152.8 or an average increase of 1.26 units per builder.

Question 4 shows that the respondents build in from one to four counties, and that 8 of the respondents build in North Florida, 26 build in Central Florida, and 16 build in South Florida. There is no significant correlation between the number of counties worked in and the time for construction, but there is a correlation between the location built in and the time for construction (F=110.58). Pairwise comparisons show that construction time is greater in South Florida than in Central or North Florida, and that construction time is greater in Central Florida than in North Florida (see Table 15). Question 5 shows that 46 of the builders now build in an area about the same size as in years previous, while three have increased the size of the area operated in, and one builds in a smaller area.

Question 6 shows that the minimum price for a house built by the respondents is $49,500 and the maximum is $295,000. The average price reported is $99,688. Questions 7, 8 and 9 show that the smallest house built by the respondents is 855 square feet of living area. The largest is 3324 square feet, and the average is 1722.3 square feet.

Regression analysis shows a significant relationship between size and time for construction (R-squared = 20.60%). However, when the data were divided into two groups, one with data from builders in South Florida and the other with data from Central and North Florida builders, neither group shows a significant correlation between house size and the time for construction.

Questionnaire Data: Supervision

Questions 10 through 13 relate to the superintendents' span of control. Question 10 shows that all of the respondents use subcontractors for 100% of the skilled work on their houses. Question 11 shows that 8 of the respondents usually have their superintendents work in only one subdivision at a time. The other 42 assign superintendents to two or three subdivisions, as can be seen from question 12. There is no significant relationship between the number of subdivisions supervised and the time for construction.

Question 13 shows that the builders reported that superintendents have to travel from one to twenty-five miles between houses that they are assigned to supervise. A significant relationship between distance traveled and time for construction (correlation = 0.3411, $P = .0154$) is shown by the data.

Questions 14 through 20 relate to factors important to motivation and control of superintendents. Questions 14 and 15 show that for most of the respondents, management decides which subcontractors and suppliers will be used on the jobs and negotiates the prices. None of the builders reported that superintendents make these decisions.

Question 16 shows that 17 of the builders have someone other than the superintendent make regular inspections of the work. There is no significant difference between whether someone else makes inspections and construction time.

Question 17 shows that 9 of the respondents have management representatives make inspections. The others use quality control or customer service departments. These inspections are made only upon completion of the house by 6 of the respondents. The other 3 also make inspections at the framing or dry-in stage of construction.

Questions 19 and 20 show that 46 of the respondents pay their superintendents regular bonuses and that 17 of these use a formula known to the superintendent to compute the amount of the bonus. For the other 13, management decides upon the amount of the bonuses. According to the data, there is no significant difference in construction time and whether the superintendents are paid a bonus, but since 92% of the respondents pay a bonus, it may be that this has an affect not shown by the statistics.

Questions 22 and 23 indicate the relative importance the builders place on the experience of superintendents. Question 22 shows that most of the builders consider the first five years of supervision experience to be very important. Experience after five years is not considered very important by many of the builders. The responses to question 23 also indicate that many builders do not believe that more than five years experience is necessary for a superintendent to reach full potential.

Questions 24 and 25 show what the respondents consider to be the greatest strengths and weaknesses of superintendents. Planning is considered the greatest strength by 36 of the builders, and inattention to details is considered the greatest weakness by 38. It is interesting to note that when the seven choices given on the questionnaire are ranked in order of their popularity, planning ranks number one on the list of greatest strengths and number two on the list of greatest weaknesses. Attention to details ranks one on the list of greatest weaknesses and is tied with communications skills for number two on the list of greatest strengths.

Question 26, ("How do your best superintendents handle that weakness?") received several answers, but the most popular was something to the effect of "They don't; we have learned to work around it."

Questionnaire Data: Scheduling

Question 21 shows that many builders consider consistency of construction time at least as important as speed of construction. Only 3 of the respondents indicated that it would be better to average 5 days less if the spread between the fastest and slowest is increased by 10 days.

Question 27 shows that for 37 of the respondents, management provides a schedule for the superintendents to follow. Question 28 shows that of the remaining 13 respondents, 8 require the superintendents to prepare a schedule for each job. This leaves 5 of the respondents (10%) who neither provide, nor require the superintendents to prepare a schedule. Production rates are significantly lower for builders who neither provide a schedule or require the superintendent to prepare one for each house. However, there is no significant difference in production rates between those who provide a schedule and those who require the superintendent to prepare one.

Question 29 shows that the most popular form of the schedule is a list of activities with dates (40 responses). CPM or PERT chart and Gantt (bar) Chart were each used by 5 of the respondents. Question 30 shows that only 3 of the builders provide their subcontractors with a copy of the schedule. Question 31 shows that 48 (96%) of the builders rely on telephone calls from the superintendent to notify the subcontractors of when to do their work. The other two send notices by mail.

Question 33 shows that 21 (42%) of the builders complete 90% or more of their houses on schedule. All of the respondents reported that they complete 75% or more of their houses on schedule. It is interesting to note that the percentage of houses completed on schedule correlates (correlation = 1) with the time allowed by the schedule (questions 38 and 39).

Questions 34 and 35 show that on average it takes 95.3 days for the builders to complete a house, but that on average they believe that they could reasonably expect to build a house in a minimum of 72.2 days. Question 36 shows that the on average the builders believe that the longest that it should take to build a house is 119.8 days. The average difference between the least and longest amount of time a builder could reasonably expect to take to build a house is 47 days. The smallest spread between the least time and the longest time given by any of the builders was 10 days, and the maximum was 65 days.

Question 37 shows that only five (10%) of the builders believe that they could build houses faster if they had fewer houses to build. Questions 38 and 39 show that the builders schedule their smallest and largest houses to be built in the same amount of time. Question 40 shows that 28 (56%) of the builders believe that they could build houses faster if the houses were physically closer together.

Question 41 shows that subcontractors not showing up when scheduled is the most common cause of construction delay (47 responses). Question 42 shows that on average the builders believe that this delays each house 6.48 days. Question 43 shows that although inspections were not given as the most common cause of delay, builders on average believe that they lose 7.7 days on each house waiting for inspections.

Question 44 was designed to close out the interview and also to attempt to form a subjective concept of what the builders see as their greatest concern. The answers varied widely, but most related to finance and marketing problems. Personnel related problems were mentioned by five of the respondents. None of the builders specifically mentioned productivity or speed of construction.

Discussion

Builder Information

The data show that the operations of the builders observed in part one and those responding to the questionnaire are similar. All of the builders observed in part one have been in business a number of years that is within the range of those responding to the questionnaire. The average years in business for the builders in part one is 11.33 and for those in part two, 10.68. The average price for a house built by builders in part one was $106,167, and the average size was 1783.33 square feet. For the builders in part two, the average price was $99,866 and the average size was 1722.3 square feet.

Neither part of the study shows any significant correlation between the number of counties worked in and the time of construction. However, the questionnaire data show a significant relationship between the part of the state worked in and the time for construction. It seems probable that some of the difference in construction time between the builders in part one from South Florida and Builders 1-1, 1-2 and 1-3 are due to the more stringent building code and the additional inspections required in South Florida.

Supervision

All of the builders in both parts of the study report that they use subcontractors for all of their skilled labor. This means that the builders' employees are only used for supervision and perhaps punchout and cleanup.

Of the builders in part one, two-thirds assigned their superintendents to two or more subdivisions at the time. Of those in part two, 84% assigned their superintendents to two or more subdivisions at the time. The data from both studies show no significant relationship between the time of construction and the number of subdivisions worked in. The data from part two show that the distance traveled may have a significant effect on the time of construction.

The data show that for all of the builders, management or purchasing departments decide which subcontractors and material suppliers to use and negotiates with the subcontractors and suppliers. Only one of the builders (Builder 4 from part one) reported that the superintendent had any input into these decisions.

The questionnaire data do not show any significant relationship between having someone other than the superintendent make inspections of the work. The data from part one do show a significant relationship.

Scheduling

Both parts of the study show that builders who either provide a schedule or require the superintendent to prepare one for each house build significantly faster than those who do neither (see Tables 11 and 12). Whether the schedule is provided by management or required of the superintendent does not significantly affect the rate of production. Data from neither part of the study indicate that the format of the schedule affects production rates. Most of the builders (4 from part 1 and 40 from part 2) use a list of activities showing scheduled start and completion dates of activities. The builders' apparent reluctance to use more sophisticated scheduling systems such as CPM may be due to a lack of understanding of the systems. Since only 5 of the builders interviewed use CPM or PERT, and none of those observed use CPM or PERT, it is possible that these programs offer benefits not shown in these data.

Disparities Between the Data From Parts 1 and 2

The following conclusions could be made from analysis of the data collected during the field observations, but are not supported by the data from the questionnaire.

1. The results of the field observations show that time of construction may be reduced if the superintendent is paid a regular bonus.
2. The results of the field observations show that time of construction may be reduced if someone other than the superintendent makes regular inspections.

3. There is no significant relationship between the distance a superintendent must travel between jobs and the time of construction.

Agreements in the Data

The following conclusions could be made from an analysis of the data from either part of the study:

1. There is a significant relationship between where a house is built and the time of construction.
2. Use of a schedule for construction of each house will result in a shorter construction time.
3. If a schedule is used, whether it is provided by management or prepared by the superintendent is not significant.
4. Whether the superintendent has input into the selection of subcontractors and suppliers has no significant effect on the time of construction.

Limitations and Qualifications

The sample used for the field observations part of the study was somewhat small; for this reason, the data will not show any differences among the builders unless the differences are quite large. Resources only allowed for weekly observations of the projects selected for part one of the study. While this is sufficient to determine the overall progress for the job, it did not provide a means of determining exactly when delays occurred or the exact reasons for the delays.

Although this sample was small, the results of the interviews (part two of the study) show that the scheduling and supervisory techniques used for the projects studied are typical of those used by other substantial builders in

Florida. Because of this and since the field observations show, without question, what has occurred on these projects, these data are indicative of what we can expect on a large percentage of the projects in Florida.

The sample used for the questionnaire was sufficiently large to yield significant statistics; however, the information was requested from the builders without prior notice. As far as could be determined, the builders did not refer to any records, but relied on memory to provide the answers. In some cases memory may not have been perfect. There is also the question of whether the builders would readily confess to the researcher that they thought some of their techniques were not completely satisfactory.

In spite of these limitations, the data do provide insight into how the builders schedule and supervise construction and guidance in how builders can improve productivity.

TABLE 4
BUILDER INFORMATION
From Part One

QUESTION	BUILDER					
	1-1	1-2	1-3	2	3	4
How many years has your company been in business?	15	15	15	4	11	8
How many houses did you build in 1990?						
Company	300	300	300	60	81	70
Superintendent	80	91	75	60	81	70
How many houses do you expect to build in 1991?						
Company	250	90	75	60	75	70
Superintendent	80	250	75	60	75	75
How many counties do you now build in?						
Company	3	3	3	2	1	1
Superintendent	1	1	2	2	1	1
How does the size of the area you now build in compare with that of previous years?	SAME	SAME	SAME	SAME	SAME	SAME
What is the price of your least expensive house?	$79,000	$80,500	$79,500	$67,500	$124,900	$149,900
What is the price of your average home?	$84,500	$86,000	$85,000	$92,500	$136,000	$165,000
What is the price of your most expensive house?	$92,000	$91,500	$92,500	$130,000	$150,000	$245,000
What is the size of the smallest house that you normally build? (square feet of living area)	1100	1100	1100	975	1750	1800
What is the size of the largest house that you normally build?	2100	2100	2100	2450	3300	2750
What is the size of your average house?	1700	1700	1700	1600	2200	2400

TABLE 5
SUPERVISION
From Part One

QUESTION	BUILDER					
	1-1	1-2	1-3	2	3	4
Span of Control						
What percentage of the work in your projects is done by subcontractors?	100	100	100	100	100	100
Do your superintendents usually work in only one subdivision at a time?	No	Yes	No	No	No	Yes
If your superintendents usually work in more than one subdivision at a time, how many?	2	N/A	3	3	3	N/A
What is the maximum distance that your superintendents have to travel between jobs? (in miles)	7	1	12	17	5	1.5
Is there an office and/or telephone for the superintendents use in each project?	No	Yes	Yes	No	No	Yes
Motivation and Control						
Who decides which subcontractors and suppliers will be used on your projects? The superintendent (S) Management (M) Purchasing department (P) Other (O)	P	P	P	M	M	M/S
Who Negotiates the prices for subcontracts and material? The superintendent (S) Management (M) Purchasing department (P) Other (O	P	P	P	M	M	M
Does anyone with your company other than the superintendent, make regular inspections on your jobs?	Yes	Yes	Yes	No	No	Yes
If someone other than the superintendent makes regular inspections, when are these inspections made?	At Final	At Final	At Final	N/A	N/A	At Framing & Final
Are your superintendents paid a regular bonus?	Yes	Yes	Yes	No	Yes	Yes
If your superintendents are paid a regular bonus, how is the amount determined?	% of salary	% of salary	% of salary	N/A	Varies	% of net profit

TABLE 5
Continued

QUESTION	BUILDER					
	1-1	1-2	1-3	2	3	4
Experience						
How many years of experience does the superintendent have?	4	6	12	9	18	15
When hiring a new superintendent, how important is experience? Rank the importance of differing years of experience from 1 to 5 with 1 being very important and 5 being not important at all						
1 year vs. none	1	1	1	1	1	1
5 years vs. 1	1	1	1	1	1	1
10 years vs. 5	5	5	5	4	5	5
15 years vs. 10	5	5	5	5	5	5
Over 15 years vs. 15	5	5	5	5	5	5
In general, how much experience does it take for your superintendents to reach their maximum potential?	5	5	5	10	5	5
Characteristics of Superintendents						
Which of the following do you think is the greatest weakness of superintendents? Poor planning. (P) Inattention to details. (D) Poor record keeping (R) Poor communications skills (S) Lack of interest in quality control (Q) Lack of interest in cost control (C) Other (O)	P	P	P	Q	D	S
Which of the following do you think is the greatest strength of superintendents? Planning (P) Attention to details (D) Communication skills (S) Interest in quality control (Q) Interest in cost control (C) Other (O)	C	C	C	C	P	P,D,& C

TABLE 6
SCHEDULING
From Part One

QUESTION	BUILDER					
	1-1	1-2	1-3	2	3	4
Does your company provide a construction schedule for your superintendents to follow?	Yes	Yes	Yes	No	No	No
If you do not provide a schedule, do you require the superintendents to make a schedule for each job?	N/A	N/A	N/A	No	No	Yes
If a schedule is provided or made, what form is used? CPM or PERT chart (C) Gannt or bar chart (B) List of activities with dates (L) Other (O)	L	L	L	N/A	N/A	L
Are subcontractors provided a copy of the schedule?	No	No	No	N/A	N/A	Yes
If subcontractors are not provided a copy of the schedule, how are they notified when to do their work? Phone call from superintendent (S) Phone call from office (P) By mail (M) Phone and mail (SM) or (PM) Other (O)	S	S	S	S	S	S
What percentage of your houses are completed on schedule?	75	80	75	50	90	95
On average how long does it take you to build a house from permit to final (In days)?						
Reported by the builder	80.	80.	80.	120.	120.	98.
Observed by researcher	94.33	75.5	86.75	125.	139.6	101.67
What is the least amount of time in which you can reasonably expect to build a house (In days)?	75	75	75	90	90	90
What is the longest amount of time for you to reasonably expect to take to build a house?	90	90	90	120	180	120
Could you build houses faster if you had fewer jobs at once?	No	No	No	Yes	No	No
How much time does your schedule allow for building your smallest house? (days)	75	75	75	90	120	90
How much time does your schedule allow for building your largest house? (days)	75	75	75	90	120	90
Could you build houses faster if the jobs were physically closer together?	Yes	Yes	Yes	Yes	No	No

TABLE 6
CONTINUED

QUESTION	BUILDER 1-1	 1-2	 1-3	 2	 3	 4
What is the most common cause of construction delay? Crews taking too long to do their work (W) Material delays (M) Change orders (C) Subcontractors not showing up when scheduled (S) Inspections (I) Rework (R) Other (O)	S	S	S	S	S	S
On average how much delay does this cause per house? (days	4-5	4-5	4-5	10	10-15	5
How much time do you lose waiting for inspections on a typical house?	10	10	10	15	30*	20
Would it be better to average 75 days per house, with some taking 85 days and some taking 65 days, or would it be better to average 80 days, with the fastest taking 77 days and the slowest 83 days? 75 day average (75) 80 day average (80)	80	80	80	80	80	80

* The builder said that much of the delay is due to re-inspections being frequently required.

TABLE 7
OBSERVED PROGRESS
From Part One

	BUILDER					
QUESTION	1-1	1-2	1-3	2	3	4
Average number of days progress made for each day worked:	.652	.812	.714	.498	.451	.602
Standard deviation in days progress for each day worked:	.072	.067	.105	.074	.095	.044
Average number of days to build each house:	94.33	75.5	86.75	125	139.6	101.67
Standard deviation of days required to build each house:	10.69	6.45	11.95	21.00	25.74	8.04

TABLE 8
COMPARISON OF CONSTRUCTION TIME
From Part One

BUILDER	1-1	1-2	1-3	2	3
1-2 Days difference Percent difference	-18.83 -24.94%				
1-3	-7.58 -8.74%	11.25 12.97%			
2	30.67 24.54%	49.5 39.60%	38.25 30.60%		
3	45.27 32.43%	64.10 45.92%	52.85 37.87%	14.60 10.46%	
4	7.34 7.22%	26.17 25.74%	14.92 14.67%	-23.33 -22.95%	-37.93 -37.31%

Note: Days difference is the average number of days required for the builder listed at the left to build a house less the average number of days required by the builder listed at the top (a negative number shows that the builder at the top averaged more days per house than the builder listed on the left).

TABLE 9
PAIRWISE COMPARISONS
From Part One

Builder	1-1	1-2	1-3	2	3
1-1					
1-2	No significant difference				
1-3	No significant difference	No significant difference			
2	Significant difference	Significant difference	Significant difference		
3	Significant difference	Significant difference	Significant difference	No significant difference	
4	No significant difference	Significant difference	No significant difference	Significant difference	Significant difference

TABLE 10
PAIRWISE COMPARISONS
ADJUSTED FOR ADDITIONAL INSPECTIONS
From Part One

Builder	1-1	1-2	1-3	2	3
1-1					
1-2	No significant difference				
1-3	No significant difference	No significant difference			
2	Significant difference	Significant difference	Significant difference		
3	Significant difference	Significant difference	No significant difference	No significant difference	
4	No significant difference	No significant difference	No significant difference	Significant difference	Significant difference

TABLE 11
PAIRWISE COMPARISON OF JOB SITE FACTORS
From Part One

Variable	Difference in Means	+- LSD	Significant Difference
Office and telephone on site (yes/no)	28.367	26.06	Yes
More than one subdivision (yes/no)	-27.898	30.14	No
Regular bonus paid (yes/no)	37.765	13.41	Yes
Scheduled provided or required (yes/no)	37.680	13.41	Yes
Scheduled provided by management (yes/no)	24.81	29.90	No
Superintendent input into which subcontractors to use (yes/no)	15.616	50.90	No
Someone other than the superintendent makes regular inspections (yes/no)	37.680	13.41	Yes

TABLE 12
PAIRWISE COMPARISON OF JOB SITE FACTORS
From Part Two

Variable	Difference in Means	+- LSD	Significant Difference
More than one subdivision (yes/no)	4.077	10.40	No
Regular bonus paid (yes/no)	4.04	14.09	No
Scheduled provided or required (yes/no)	18.56	11.95	Yes
Scheduled provided by management (yes/no)	3.23	8.69	No
Superintendent input into which subcontractors to use (yes/no)	1.67	9.96	No
Someone other than the superintendent makes regular inspections (yes/no)	37.680	13.41	Yes

TABLE 13
COMPARISONS OF TIME OF CONSTRUCTION BY GEOGRAPHICAL AREA
From Part Two

Areas Compared	Difference in Means	+- LSD	Significant Difference
North - Central	-9.952	4.636	Yes
North - South	-37.500	4.965	Yes
Central - South	-27.548	3.643	Yes

TABLE 14
COMPARISONS OF HOUSE SIZE BY GEOGRAPHICAL AREA
From Part Two

Areas Compared	Difference in Means	+- LSD	Significant Difference
North - Central	-132.46	295.37	Yes
North - South	-496.63	316.34	Yes
Central - South	-364.16	232.13	Yes

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of the research closely support the research model but suggest minor revisions. After analyzing the data, the model might be changed from

$$T: T(S_m, SC_m, SC_s, SC_u, SP_B, SP_I, SP_O, SP_E, SP_e)$$

to

$$T=T(S_m, SC, SC_u, SP_B, SP_I, SP_O, SP_E, BC)$$

where

T = Total construction time

S_m = The time allowed by the model schedule

SC_s = The effect of management providing a schedule

SC_s = The effect of requiring the superintendent to prepare a schedule

SC = The effect of management providing a schedule requiring the superintendent to prepare one.

SC_u = The effect of providing subcontractors with a copy of the schedule

SP_o = The effect of having a superintendent work in only one subdivision at a time

SP_I = The effect of someone other than the superintendent making regular inspections

SP_B = The effect of paying the superintendent a regular bonus

SP_E = The effect of management emphasis on high productivity

BC = The effect of building codes.

SP_e = The effect of superintendent experience

Although the revisions are minor, they reflect the data showing the following:

1. That there seems to be no difference in production rates whether management provides a schedule or requires the superintendent to prepare one, so long as one is used.
2. The data indicate that location or building codes are an important variable in the time required to build a house.
3. There is no indication in the data that the amount of experience the superintendent has is a factor.

The average time taken by all of the builders participating in the study was 96.22 days. Although this is less than the 192 day national average as reported by the National Association of Home Builders, it is much longer than the 61 days expected by the model schedule. The model schedule is, of course, idealistic, but none of the builders who have reviewed it thought that it was not possible to meet. The builders thought that they probably would not meet the model schedule on a regular basis because it does not allow for any contingencies. All of the builders who reviewed the schedule agreed that the times allowed for the various activities should be sufficient, but they felt that some delays due to weather, subcontractors not arriving at the job site when scheduled and delays awaiting inspections are inevitable. The builders interviewed reported that subcontractors not arriving at the job site was the most common cause of delay, and the average delay reported was 6.48 days. The builders interviewed also reported that the time spent awaiting inspections averages 7.7 days. The combined average delay caused by subcontractors arriving late and waiting for inspections is 14.18 days. This is far short of the difference predicted by the model schedule and the 95.3 days reported by the builders interviewed. Exactly why it takes the builders over 57% longer than the model schedule is still not clear. It is clear, however, that many builders could reduce the time required to build houses. The builders should assign superintendents to projects so as to reduce the travel between jobs to a minimum. The builders should either provide a well-thought-out schedule, or require the superintendents to make one for each job. An office of some sort and a telephone should be provided on each project. Although the data are not clear on the effects of paying regular bonuses to superintendents, since 92% of the builders in the study do so, this may have become almost a necessity in order to recruit and retain qualified superintendents.

The data show that many of the builders complete 90% of their houses on schedule, and that the builders' scheduled time is directly related to the time it takes them to build. It could be logically concluded that over time, the builders have adopted schedules to fit performance. This is a reasonable procedure from the standpoint of planning for cash flow, sales and future job starts. Never-the-less, construction time could ultimately be reduced if the builders would develop a reasonable but taxing schedule, and then seek methods which would allow meeting the schedule.

Recommendations

Management Paradigm

Analysis of the results of both parts of this study show that builders could improve the efficiency of their overall operations if they would incorporate the following management techniques into their operations:

Scheduling

There should be a well-thought-out schedule prepared for each house to be built. The format of the schedule is not critical. If management believes it necessary to show the precedence relationships of the various work activities, then a network diagram such as a CPM should be used. If management believes that the superintendent and subcontractors have sufficient understanding of the precedence relationships among the work activities, then a bar chart or list of activities with scheduled starting and finishing dates will be adequate. Whether the schedule is prepared by the superintendent or is provided by management is not important. The time allowed by the schedule should be reasonable, but somewhat taxing. Completing the jobs on time according to a lax schedule does not promote improved productivity.

The problem of subcontractors not arriving at the job when scheduled should be addressed. Subcontractors should be provided a schedule well in advance of the time their work is needed and steps should be taken to be certain that all subcontractors and material suppliers are given adequate notice of any changes in the schedule.

Supervision

When recruiting superintendents, management should not place undue emphasis on experience beyond 5 years. This study has shown that most builders have found that experience beyond that level is of little importance. Management should continuously place emphasis on the importance of attention to details by the superintendents. This aspect should be emphasized in all continuing education and training programs. Builders should seek out educational programs which will help the superintendents improve their skills in the areas of attention to details and planning. Community colleges and universities throughout Florida could be helpful in developing and offering such courses. These courses should emphasize the underlying importance of planning and scheduling as well as the mechanics of the various scheduling programs.

Management should make supervision assignments so as to minimize to the extent possible the travel time between jobs. An office of some sort (a desk and a telephone) should be provided on each project for the superintendent's use. Superintendents should be paid regular bonuses based on performance. The bonuses should be calculated by a formula know and understood by the superintendents.

Subcontracts and purchase orders should be negotiated by whoever in the organization is best suited for, and has the most time for the task. This study shows that there is no effect on productivity whether or not this is done by the superintendent.

Other

Builders should become more interested in improving productivity. It became apparent during this study that builders are not much concerned with construction productivity. As one builder said, "I can show that there are over 20,000 separate items in each house and over 200 local people are involved in putting the pieces together; the fact that we get them built at all is a miracle." His point is well taken, but Mayer's quote (see page 2) comes to mind. The builder can survive and even prosper because for the most part his competition is not doing any better. At some point, someone will solve the complicated scheduling problems associated with homebuilding. If it is not indigenous builders, then this industry may be facing problems similar to those faced by the American automobile industry.

Builders could use the model schedule and cost as a means of measuring their production against a tough standard. Over time, this would provide the builders a clear indication of the efficiency of their operations. The results of such measurements would also provide a useful tool for projecting cash flow requirements.

Building officials and local legislative bodies should exercise care in adopting more strenuous codes and calling for additional inspections. Some jurisdictions might examine the regulations already in place to be sure that unnecessary inspections are not delaying construction. Consideration should be given to instituting a system of self-inspection in which registered and licensed builders could make some of the less critical inspections and certify to the building official that the work was according to the applicable codes and standards.

Future Research

Since the sample for the field observations was small, it would be useful to conduct a large scale study of this type. Ideally, the researchers could observe operations in 25 or more projects on a daily basis. Through these observations and discussions with superintendents and subcontractors, it might be possible to determine exactly when delays occurred and the causes of the delays.

Additional studies should be conducted to determine whether the technique of measuring progress by comparing the value of work in place per day worked among various projects is reasonable for other types of construction. School buildings are one example of a type of construction where this method might be feasible.

APPENDIX

BUILDER QUESTIONNAIRE

Company ______________________________

Respondent ______________________________

Title (position) __________________________

Company Information

1. How long has your company been in house building? ________ years

2. How many houses did you build in 1990? ________

3. How many houses to you expect to build in 1991? ________

4. In what counties do you currently build?

   ____

5. How does the size of the area in which you build compare to that of previous years? (Check one)

   ( ) Larger ( ) Smaller ( ) About the same

6. What is the price range of your homes?

   Least expensive $ ____________, Average cost $ ____________,

   Most expensive $ ____________,.

7. How big is the smallest house that you normally build? __________SF

8. How big is the average house that you normally build? __________SF

9. How big is the largest house that you normally build? __________SF

Management

10. What percentage of the work in your projects is performed by subcontractors? __________%

11. Do your superintendents usually work in only one subdivision at a time?

    (Check one) ( )YES ( )NO

12. If no, what is the usual number of subdivisions? ________

13. What is the maximum distance (in miles) that your superintendents have to travel between jobs?

    ______

14. Who decides which subcontractors and suppliers will be used on your jobs? (Check one)

( ) The superintendent, ( ) Management,

( ) Purchasing department, ( ) Other

If other, please describe. ____

____

15. Who negotiates the prices for labor and material? (Check one)

( ) The superintendent, ( ) Management,

( ) Purchasing department, ( ) Other

If other, please describe.

____

16. Does anyone with your company, other than the superintendent, make regular inspections on your jobs?

(Check one) ( ) YES ( ) NO

17. If yes, who makes these inspections?

____

____

18. When are these inspections made?

____

19. Are your superintendents paid a regular bonus? (Check one) ( ) YES ( ) NO

20. If yes, how is the amount determined?

____

21. Would it be better to average 75 days per house, with some taking 85 days and some 65 days, or would it be better to average 80 days, with the fastest being 77 days and the slowest being 83 days? (Check one)

( ) 75 days average ( ) 80 days average

Experience

22. When hiring a new superintendent, how important is experience?

Please rank the importance of differing years of experience from 1 to 5, with 1 being very important and 5 being not important at all. (Check one for each line)

1 year vs. none	( )1	( )2	( )3	( )4	( )5
5 years vs. 1 year	( )1	( )2	( )3	( )4	( )5
10 years vs. 5 years	( )1	( )2	( )3	( )4	( )5
15 years vs. 10 years	( )1	( )2	( )3	( )4	( )5
Over 15 years vs. 15 years	( )1	( )2	( )3	( )4	( )5

23. In general, how much experience does it take for your superintendents to reach their maximum potential?

_________ years.

Supervision

24. Which of the following do you think is the greatest weakness of construction superintendents? (Check one)

( ) Poor planning ( ) Poor communications skills

( ) Inattention to details ( ) Poor record keeping

( ) Lack of interest in quality control

( ) Lack of interest in cost control

( ) Other ______________________________________

Please explain your answer. ______________________________________

____

25. How do your best superintendents handle that weakness?

26. Which of the following do you think is the greatest strength of construction superintendents?

( ) Poor planning ( ) Poor communications skills

( ) Inattention to details ( ) Poor record keeping

( ) Lack of interest in quality control

( ) Lack of interest in cost control

( ) Other ______________________________________

Please explain your answer. ______________________________________

Scheduling

27. Does your company provide a construction schedule for your superintendents to follow? (Check one)

( ) YES ( ) NO

28. If you do not provide a schedule, do you require the superintendents to make a schedule for each job?

(Check one) ( ) YES ( ) NO

29. If a schedule is provided, or made, what form is used? (Check one)

( ) CPM or PERT chart ( ) Gannt (bar) chart

( ) List of activities with dates ( ) Other

If other, please describe. ______________________________________

____

30. Are subcontractors provided a copy of the schedule?

(Check one) ( ) YES ( ) NO

31. If not, how are the subcontractors notified when to do their work? (Check one)

( ) By Phone call from the superintendent

( ) By Phone call from the office

( ) By Mail

( ) Other. Please explain

____

32. When are subs notified of work to be done? ____

____

33. What percentage of your houses are completed on schedule? ________%

34. On average, how long does it take you to build a house from permit to final?

________ days.

35. What is the least amount of time in which you can reasonably expect to build a house?

________days.

36. What is the longest amount of time for you to reasonably expect to take to build a house?

________ days

37. Would you build houses faster if you had fewer jobs at once? (Check one) ( ) YES ( ) NO

38. How much time does your schedule allow for building your smallest house?

________ days

39. How much time does your schedule allow for building your largest house?

________ days

40. Would you build houses faster if the jobs were physically closer together? (Check one)

( ) YES ( ) NO

41. What is the most common cause of construction delay? (Check one)

( ) Crews taking too long to complete their work
( ) Subcontractors not showing up when scheduled
( ) Material delays ( ) Inspections
( ) Change orders ( ) Rework
( ) Other

____

42. On average how much delay does this cause per house?

________days

43. How much time do you lose waiting for inspections on a typical house?

________days

44. If you could wave a magic wand and change one thing to improve your projects, what would you change?

____

____

RESULTS OF BUILDER QUESTIONNAIRE

Company ____________________

Respondent ____________________

Title (position) ____________________

Company Information

1. How long has your company been in house building?

   Minimum: 3 years Maximum: 23 years Mean: 10.68

2. How many houses did you build in 1990?

   Minimum: 100 Maximum: 200 Mean: 150.54

3. How many houses to you expect to build in 1991? ________

   Minimum: 100 Maximum: 200 Mean: 152.8

4. In what counties do you currently build?

Number of counties:	1	2	3	4
Responses:	8	18	20	4
Location:	North	Central	South	
Responses:	8	26	16	

5. How does the size of the area in which you build compare to that of previous years? (Check one)

Answer: Larger	Smaller	About the same
3	1	46

6. What is the price range of your homes?

	Minimum	Maximum	Mean
Least expensive:	$49,500	$240,000	$93,038
Average cost	57,500	250,000	99,688
Most expensive	75,000	295,000	122,480

7. How big is the smallest house that you normally build (in Square feet)?

Minimum	Maximum	Mean
855	2475	1539.34

8. How big is the average house that you normally build?

Minimum	Maximum	Mean
985	2750	1722.3

9. How big is the largest house that you normally build?

Minimum	Maximum	Mean
1372	3342	2104.52

Management

10. What percentage of the work in your projects is performed by subcontractors?

    All respondents: 100%

11. Do your superintendents usually work in only one subdivision at a time?

Answer:	YES	NO
Responses	8	42

12. If no, what is the usual number of subdivisions?

Answer:	2	3
Responses:	38	4

13. What is the maximum distance (in miles) that your superintendents have to travel between jobs?

Minimum	Maximum	Mean
1	25	11.18

14. Who decides which subcontractors and suppliers will be used on your jobs? (Check one)

Answer:	The superintendent	Management	Purchasing Department	Other
Responses:	0	45	5	0

15. Who negotiates the prices for labor and material? (Check one)

Answer:	The superintendent	Management	Purchasing Department	Other
Responses:	0	41	9	0

16. Does anyone with your company other than the superintendent make regular inspections on your jobs?

Answer:	Yes	No
Responses	17	33

17. If yes, who makes these inspections?

Answer:	Management	Q.C. or Customer Service
Responses	9	8

18. When are these inspections made?

Answer:	At Final	At Framing or Dry-in
Responses	29	4

19. Are your superintendents paid a regular bonus?

Answer:	Yes	No
	46	4

20. If yes, how is the amount determined?

Answer:	Known formula	Arbitrary
	14	33

21. Would it be better to average 75 days per house, with some taking 85 days and some 65 days, or would it be better to average 80 days, with the fastest being 77 days and the slowest being 83 days?

Answer:	75 days average	80 days average
Responses:	3	47

Experience

22. When hiring a new superintendent, how important is experience?

Please rank the importance of differing years of experience from 1 to 5, with 1 being very important and 5 being not important at all. (Check one for each line)

1 year vs. none

Answer:	1	2	3	4	5
Responses:	0	0	0	0	50

5 years vs. 1 year

Answer:	1	2	3	4	5
Responses:	0	0	0	1	49

10 years vs. 5 years

Answer:	1	2	3	4	5
Responses:	40	3	3	3	1

15 years vs. 10 years

Answer:	1	2	3	4	5
Responses:	43	5	1	1	0

Over 15 years vs.
15 years

Answer:	1	2	3	4	5
Responses:	49	0	0	1	0

23. In general, how much experience does it take for your superintendents to reach their maximum potential (in years)?

Answer:	5	10	15	20
Responses:	43	3	3	1

Supervision

24. Which of the following do you think is the greatest weakness of construction superintendents?

Answer	Responses
Poor planning	7
Poor communications skills	1
Inattention to details	38
Poor record keeping	0
Lack of interest in quality control	1
Lack of interest in cost control	0
Other	2

25. How do your best superintendents handle that weakness?
Answers varied, but the most common was to the effect of "They do not, we have learned to work around it."

26. Which of the following do you think is the greatest strength of construction superintendents?

Answer	Responses
Planning	36
Communications skills	4
Attention to details	4
Record keeping	3
Interest in quality control	0
Interest in cost control	1
Other	2

Scheduling

27. Does your company provide a construction schedule for your superintendents to follow?

Answer:	Yes	No
Responses:	37	13

28. If you do not provide a schedule, do you require the superintendents to make a schedule for each job?

Answer:	Yes	No
Responses:	8	5

29. If a schedule is provided or made, what form is used?

Answer:	Responses:
CPM or PERT chart	5
Gannt (bar) chart	5
List of activities with dates	40
Other	0

30. Are subcontractors provided a copy of the schedule?

Answer:	Yes	No
Responses:	3	47

31. If not, how are the subcontractors notified when to do their work? (Check one)

Answer:	Responses:
By Phone call from the superintendent	48
By Phone call from the office	0
By Mail	2
Other	0

32. When are subs notified of work to be done.

Answer:	One week early	Two days early	At superintendents discretion
Responses:	36	2	12

33. What percentage of your houses are completed on schedule?

Answer:	Responses:
75%	5
80%	10
85%	7
90%	20
98%	1

34. On average, how long does it take you to build a house from permit to final?

Minimum: 75 days Maximum: 120 days Mean: 95.3 days

35. What is the least amount of time in which you can reasonably expect to build a house?

Minimum: 60 days Maximum: 90 days Mean: 72.2 days

36. What is the longest amount of time for you to reasonably expect to take to build a house?

Minimum: 70 days Maximum: 150 days Mean: 119.1 days

37. Would you build houses faster if you had fewer jobs at once?

Answer:	Yes	No
Responses:	5	45

38. How much time does your schedule allow for building your smallest house?

Minimum: 75 days Maximum: 98 days Mean: 86.66 days

39. How much time does your schedule allow for building your largest house?

Minimum: 75 days Maximum: 98 days Mean: 86.66 days

40. Would you build houses faster if the jobs were physically closer together? (Check one)

Answer:	Yes	No
Responses:	28	22

41. What is the most common cause of construction delay?

Answer:	Responses:
Crews taking too long to complete their work	1
Subcontractors not showing up when scheduled	47
Material delays	0
Inspections	1
Change orders	1
Rework	0
Other	0

42. On average how much delay does this cause per house?

Minimum: 4 Maximum: 15 Mean: 6.48

43. How much time do you lose waiting for inspections on a typical house?

Minimum: 5 Maximum: 30 Mean: 7.7

Answer:	5	10	15	25	30
Responses:	31	16	1	1	1

44. If you could waive a magic wand and change one thing to improve your projects, what would you change?

Answers varied, but none specifically mentioned productivity problems.

EXAMPLE OF WEEKLY OBSERVATIONS

Builder 4-Job 9

Date	
28-Dec-89	Job started (released for construction)
08-Jan-90	Building permit issued (from posted permit)
10-Jan-90	Rough grade inspection (from posted permit)
16-Jan-90	Slab inspection (from posted permit)
23-Jan-90	Bond beam inspection (from posted permit)
26-Jan-90	Tie beam stripped except for beam bottom trusses on roof sheathing about 1/2 completed. No activity observed.
30-Jan-90	Sheathing inspection (FPP)
30-Jan-90	Truss inspection (FPP)
02-Feb-90	Roof dried in and flashed Interior partitions being framed
06-Feb-90	A-C rough inspection (FPP)
08-Feb-90	Plumbing top out inspection (FPP) Rough electrical inspection (FPP)
09-Feb-90	Framing inspection (FPP)
10-Feb-90	Windows installed Rear porch poured No activity observed
13-Feb-90	Insulation inspection (FPP)
16-Feb-90	Dry-wall hung--not taped Exterior stucco being applied Roof stocked
20-Feb-90	Drywall inspection (FPP)
23-Feb-90	Exterior stucco complete Dry-wall sprayed--not painted
02-Mar-90	Roof completed Trim carpentry complete ceramic tile in
08-Mar-90	Roof inspection (FPP)
10-Mar-90	House locked up Exterior painted Interior painted Cabinets & vanities in Plumbing and electrical trim complete
14-Mar-90	Plumbing final inspection (FPP)
16-Mar-90	Drive poured Mechanical trim complete Closet shelves going in
23-Mar-90	Mirrors & medicine cabinets in Landscaping & sod in
26-Mar-90	Mechanical final inspection (FPP)
27-Mar-90	Electrical final inspection (FPP)
30-Mar-90	Carpet in
06-Apr-90	Carpentry bump-out complete Still no vinyl floor covering
13-Apr-90	All observable items complete
04-May-90	Final inspection (FPP)

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BIOGRAPHICAL SKETCH

Leon Wetherington was born on November 19, 1939, near Plant City, Florida. He was the second of six children of Lee Horace Wetherington, a carpenter, and Velma Tomberlin Wetherington.

Leon was educated in the local school system and graduated from Plant City Senior High in 1958.

He enlisted in the Navy in 1958, and after basic training, completed the Navy's Class A Builder's School in Port Hueneme, California, graduating first in the class.

Attached to USN MCB Three on Okinawa and Guam from 1959 to 1962, he was involved in various construction activities including concrete form building and placement, trim carpentry, and concrete block masonry.

After being honorably discharged from the Navy in 1962, Leon became an independent contractor installing kitchen cabinets, aluminum windows, and other products until 1965. In 1965 he went to work for the Allen M. Campbell Construction Company. While on assignment in Gainesville, Florida, he met a recent graduate of the Department of Building Construction of the University of Florida who encouraged him to seek an education at that school. After a meeting with Professor Loys Johnson, the director of that department, Leon returned to central Florida where he received an A.A. degree from Polk Junior College in December of 1967. He then enrolled in the Department of Building Construction and received the Bachelor of Building Construction degree in August of 1969.

Upon graduation, Leon returned to Allen M. Campbell Company as a project engineer in South Carolina. In 1971 he returned to Florida, employed by Laurel Builders, Inc., of Fern Park, as a project superintendent. He held various positions with that firm and became its president in 1976. He resigned that position in June of 1985 to return to school with the goal of becoming a teacher. He received the Master of Building Construction degree from the University of Florida in August of 1987, and has since been working on a Ph.D. while teaching part-time in the School of Building Construction at the University of Florida.

Leon has been married to the former Marilyn Edwards, whom he first met at the age of four, since 1960. They have two sons, Daniel and Kenneth.

Leon is a member of the Southern Standard Building Code Congress and is a registered general contractor and a licensed real estate broker.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Weilin Chang, Chair
Professor of Building Construction

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Carleton Coulter III
Professor of Building Construction

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Rodney E Cox

Rodney Cox
Professor of Building Construction

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James L Wattenbarger

James L. Wattenbarger
Professor of Education Leadership

This dissertation was submitted to the Graduate Faculty of the College of Architecture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May, 1992

Dean, College of Architecture

Dean, Graduate School